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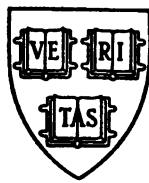
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MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF HOLDERNESS, AND THE ADJOINING PARTS OF YORKSHIRE AND LINCOLNSHIRE.

BY

CLEMENT REID, F.G.S.

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N O T I C E.

THE present Memoir is essentially a contribution to our knowledge of the Glacial geology of Britain. It deals with a remarkable area comprised in the old district of Holderness and in adjoining parts of the Yorkshire and Lincolnshire coasts. Flamborough Head limits this area on the north, and the chalk downs stretch thence for some way southwards as its western boundary. Against these uplands and in the depression to the east and south of them a series of glacial, inter-glacial and post-glacial deposits has been accumulated to a depth of about 100 feet. The almost continuous range of coast-cliffs from Flamborough Head to the Mouth of the Humber exposes interesting sections of the boulder-clays with transported stones from remote and widely separated sources, among which are Cumberland, the Cheviot Hills, and the mountains of Scandinavia. Besides these erratic blocks the same deposits furnish also pieces of sand and clay (Bridlington Crag) which, containing an intensely arctic fauna, have evidently been torn away and transported from some submarine accumulation of the same period. The inter-glacial beds, which cover considerable spaces, have yielded mammalian bones and a marine fauna indicating a climate that seems to have been little if at all colder than that of the same region at present.

Another interesting feature of the ground, described in the following pages, is the rapid encroachment of the sea and the serious loss of land along this coast-line within historic times. The average rate of advance of the sea has been about $2\frac{1}{4}$ yards a year for the last 200 years. The map, Sheet 85, affords melancholy evidence of this change; it was originally published in 1824, and on the Geological Survey edition of it the difference is shown between the coast-line in that year and in 1881 when the Geological Survey of the ground was made. While these shores are being wasted, considerable tracts of land have been gained in the Humber estuary. The account here given of the changes in that district is taken mainly from published sources.

ARCH. GEIKIE,

Geological Survey Office, Director General.
28 Jermyn Street, London,
10th June, 1885.

NOTICE.

THIS Memoir describes the Glacial and Post-glacial Deposits of Holderness and the adjoining parts of Yorkshire and Lincolnshire. It refers to Sheets 85, 94 S.E. and N.E., and also to considerable areas in 85, 94 S.W. and N.W. Of this area the northern and north-western portions were mapped by Mr. Dakyns, who in conjunction with Mr. Fox-Strangways has written an explanation of Sheet 94 N.E. A portion of Sheet 86, near Hull and Hessle, was mapped by Mr. Cameron. The rest of the area was surveyed by Mr. Clement Reid, who also has personal knowledge of the whole. In the description of the Bridlington Crag and the Glacial Beds near Bridlington much use has been made of Mr. Lamplugh's published papers. The thanks of the Geological Survey are also due to him, as well as to the Council of the Yorkshire Geological Society, for permission to use several illustrations which have appeared in the Proceedings of that Society. To Mr. Mortimer of Driffield and to Mr. Cordeaux the Survey is also indebted for their contributions of valuable notes.

Geological Survey Office,
28 Jermyn Street, S.W.,
10 June 1885.

H. W. BRISTOW,
Senior Director.

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THE GEOLOGY OF
HOLDERNESS,
AND THE ADJOINING PARTS OF YORKSHIRE
AND LINCOLNSHIRE.

CHAPTER I.

ORIGIN AND PHYSICAL FEATURES OF
HOLDERNESS.

THE great hardness of the Lower Chalk of Yorkshire causes it to wear less rapidly than the softer beds on either side. Thus by the denudation of Filey and Bridlington Bays the bold headland has been left which now projects into the sea at Flamborough. This head forms the northern boundary both of Bridlington Bay and of the low-lying district of Holderness.

Inland a continuation of the same high Chalk Wolds, trending southward, defines the Holderness plain, and marks by its abrupt eastern margin the position of an ancient buried and degraded sea cliff. This cliff passes through Bridlington, Driffield, Beverley, and Cottingham, to Hessle, where it is broken through by the Humber. South of the Humber it turns to the south-east, through Thornton, Ulceby, Keelby, Laceby, Hawerby, and Ludborough; its position being still marked by a more or less sharp rise of the Chalk from beneath the Boulder Clay. South of Ludborough it stretches south-eastward beyond the district described in this Memoir.

Though the southern boundary of this old bay is somewhat indefinite, yet practically Donna Nook and Ludborough form a very convenient limit; for the Boulder Clay flat has there dwindled to a narrow strip, in which sections are extremely rare.

Geologically, Holderness is the district between the ancient cliff and the sea, though the legal division (the "Seigniory of Holderness"), comprising merely the portion of Yorkshire east of the River Hull, is considerably smaller.

Besides the old Bay of Holderness this Memoir describes the outlying patches of Drift which, though properly belonging to Holderness, occur at various heights on the Chalk Wolds. Few of these are found at a greater height than 200 feet, except near Flamborough. Above that level there is usually a high-lying tract of bare Chalk, extending to the edge of the escarpment.

This ridge of Chalk separates the Pleistocene deposits of Holderness from those west of the Wold. Thus there is a well defined district, bounded on the north, west, and south-east by the Chalk Wolds, and on the east by the North Sea, over which the Drifts possess a uniform character, and evidently have had a common origin. Holderness is only connected with other districts by a strip of Drift near Luddborough, and by another passing through the Humber Valley.

The origin of the Holderness Bay is very simple. The Lower Chalk of Yorkshire and Lincolnshire is hard, and the Middle Chalk both hard and flinty; the Upper Chalk, however, is softer, and free from flints. A synclinal causes the Upper Chalk to underlie great part of the low-lands of Holderness, this division alone reaching a thickness of upwards of 800 feet near the centre of the basin, at Hornsea. Ordinary marine denudation at some former period has cut back the softer Chalk, and left the harder portion projecting in a bold headland.

This denudation must have been greatly facilitated by the absence of flints in the Upper Chalk, and by the non-occurrence at that period of the Drift beds, which now yield such an abundant supply of boulders. A Chalk cliff unprotected by a shingle beach would be wasted at a much more rapid rate than a cliff of flinty Chalk, even if the Chalk itself were of the same hardness. This erosion of the softer beds has caused a bay to be cut out, the outline of which follows very nearly the curved strike of the beds.

Of the date of formation of this bay there is no direct evidence, except that it is clearly more ancient than the oldest remaining Pleistocene deposits of East Yorkshire. There can be little doubt that it existed in Pliocene times, though as yet no beds of that age have been discovered in it. Probably further search may prove their occurrence in patches beneath the Boulder Clay.

Subsequent changes have been essentially conservative. Ice has filled the bay with enormous masses of far-transported Drift, which have been banked against, and have preserved, the old line of cliff, and by their accumulation have almost obliterated this ancient "Bay of Holderness." Since the Glacial Period a small portion of this great bay has been re-excavated, and year by year what is now only "Bridlington" Bay is enlarged, and approaches more nearly to its old limits.

About the centre of the bay, the Chalk Wold is broken through by the valley of the Humber. From the fact of its cutting through the escarpment of the Chalk, instead of turning southward along the flat lands of the Ancholme, it is evident that the Humber must have existed when the bottom of the Ancholme Valley stood at least 200 feet above its present level. Thus it is clear that the Humber must be of very ancient date, for there is no mode of escape of the drainage water of a large portion of England except through this gap. Probably the present course of the Humber, like that of most of the rivers which breach the escarpments in England, dates back to Miocene times.

The deposits which fill the old bay are, in the main, of Glacial age and origin. Inter-glacial Gravels also occur sparingly, and superficial Alluvium covers large areas, especially near the Humber. The bulk of the Drift, however, consists of Boulder Clay.

This large area of clay land forms a flat or very gently undulating country, only at one point reaching a height of over 100 feet. More elevated land probably at one time existed near the present coast; for the general drainage is inland, towards the River Hull, instead of direct to the sea. Dimlington High Land, 139 ft. when the Ordnance map was made (1852-3), but now lower and rapidly decreasing, is apparently the sole relic of a belt or long mound of Drift skirting the coast, and throwing the drainage inland in much the same way as it does in Filey Bay, or in Norfolk. Probably it is this mound which has also caused the post-glacial Humber to turn south-eastward in such a marked manner after leaving the Chalk. Further on it will be shown that this mound is not improbably part of the original structure of the country, representing roughly the contour as left by the ice, and is not a denudation feature. (See p. 35).

The scenery produced by the Boulder Clay is naturally very tame, and the land is so thoroughly cultivated that, except at a few spots, there is now no trace of its original character. The meres which were once so characteristic of Holderness have all been drained, with the single exception of that of Hornsea; and even there the woods are planted, and are not the original growth. But the constant occurrence of the name "mere" in places where there are now only ploughed fields, shows well the original state of the country. Looking at the fertile fields of Holderness it is difficult to realize the appearance of the country before it was drained. Then much of it must have been almost impenetrable, the isolated hills of Boulder Clay being separated from each other by swamps impassable either on foot or in boats. In winter these hills must have been transformed into true islands, as is sometimes the case even at the present day.

The sand dunes of Spurn Head and Donna Nook exhibit scenery of a totally different character. To any one but a naturalist or geologist these sand dunes will probably seem very uninteresting; but they are well worth visiting, for they show clearly how the sea throws up a barrier against its own advance, and may protect a low-lying coast or harbour from any sudden storm. The protecting bank, being the result of the average force of the winds and seas acting during a long time, is not easily moved by a single storm.

The foreshores of the Humber, when the tide is out, are generally wide flats of bare mud or sand, cut up by multitudes of channels and creeks, and passing upwards into salt marshes. Large numbers of wild-fowl and sea-birds feed on these flats, but they cannot usually be called either picturesque or pleasant to walk upon. Altogether the scenery near the mouth of the Humber reminds one very much of that of Holland.

CHAPTER II.

BOULDER CLAY.

BASEMENT CLAY.

There being considerable doubt as to the exact correlation and succession of the different Pleistocene deposits in Holderness, as a matter of convenience the Boulder Clays will be described first, the stratified Glacial and Inter-glacial Beds being taken in separate chapters.

In the cliffs of Holderness, where the succession is most complete, the Boulder Clay is in four divisions, known respectively as the Basement Clay, the Lower and Upper Purple Clay, and the Hessle Clay (*of the coast section*). These are separated from each other by partings, which in places take the form of beds of stratified gravel, sand, or clay. Even where the partings are merely lines in an otherwise homogeneous Boulder Clay, they can be traced for such long distances as to form useful horizons. What may be the real value of these lines of division we do not at present know; but as they have an existence and can be traced, it will be desirable to describe separately each of the Boulder Clays. Some of the intercalated stratified beds may turn out to represent true inter-glacial periods: one has already done so.

The oldest Boulder Clay seen in the cliff has been named by Mr. S. V. Wood, junior, the "Basement Clay." This name was given because the foot of the cliff sometimes consists of a Clay of marked lithological character, and it was apparently concluded that this deposit was the lowest bed in Holderness. The name is generally used, and is a convenient one to adopt, remembering that it refers to the base of the cliff, and not to the bed resting directly on the Chalk. It should not be forgotten that the Chalk is generally about 60 feet beneath the sea-level, and that there are still these 60 feet of deposits only imperfectly known through borings. The 60 feet may include not only Boulder Clays older than the so-called Basement Clay, but even representatives of the Newer Pliocene Beds so well seen in Norfolk.

The Basement Clay is a dark green or bluish Boulder Clay, containing numerous boulders of far transported rock, and a moderate amount of the local Chalk. Its most marked characteristic, and one that distinguishes it from every other Boulder Clay in the East of England, is the common occurrence in it of transported masses of sand and clay full of mollusca, often quite

uninjured and with the valves united. These masses of fossiliferous sand and clay have commonly been considered to be beds in place, and under the name " Bridlington Crag " are constantly mentioned in manuals and by writers on Holderness geology. The shells were first discovered by Prof. Sedgwick during an excursion made in the year 1821, but he appears to have considered that they might be of Eocene age. There has been so much discussion as to the real nature and age of the deposit, and it is so commonly accepted as an undisturbed stratified bed, that it will be advisable to quote verbatim the accounts of those geologists who actually examined it.

Prof. Sedgwick, writing in 1826, states that in 1821, " By the degradation of the coast immediately on the north side of Bridlington Quay, a bed of green-sand, extending through a distance of eight or ten yards, was laid bare at the base of the cliff. It contained many incoherent bivalve shells, and very much resembled some of the beds which are found in the higher part of the sand-pits at Woolwich. I considered it an undoubted proof of, at least, a partial existence of *tertiary* beds in that part of England. With the *crag* of Suffolk, it ought not, I think, to be confounded." Later in the same year it was hidden by the sea-defences.*

What appears to have been the same deposit was re-discovered in 1835 by Mr. W. Bean, who mentions a section exposed on the north side of the harbour, near the Esplanade. He describes " a heterogeneous mass, only a few yards long and as many high composed of sand, clay, marine shells, and pebbles of every description; chalk and flint pebbles were, as might be expected, most abundant The colour and appearance of this shelly mass resemble the London Clay, but the fossils have the character of those found in the *crag* formation: [the shelly bed contains] a greater number of species than have been at present obtained, and much caution will be requisite ere its geological position can be truly determined. Thus much, however, is certain, that these shells are coeval with, if not of higher antiquity than the *crag*."†

Immediately after Mr. Bean's discovery Prof. Phillips examined the section. Writing in 1835 he alludes to the bed,‡ but most of his notes made at the time appear not to have been published till 1875.§

His description is very clear and exact. He states that " When I examined the spot after this discovery, I found the shelly bed largely exposed, very irregular in its upper surface, covered by

* Prof. A. Sedgwick: "On the Classification of the Strata which appear on the Yorkshire Coast."—*Ann. of Phil.*, ser. 2, vol. xi. p. 339.

† W. Bean: "A short Account of an interesting Deposit of Fossil Shells at Burlington Quay."—*Mag. Nat. Hist.*, vol. viii. p. 355.

‡ Prof. J. Phillips: "Notice of a newly discovered Tertiary Deposit on the coast of Yorkshire (Bridlington)."—*Rep. Brit. Assoc.* for 1835, *Trans. of Sections*, p. 62.

§ Illustrations of the Geology of Yorkshire. Pt. I.—The Yorkshire Coast. 3rd edit. p. 87.

boulder-drift, and composed of dark sandy clay with small black pebbles, and chalk and flint fragments, mixed with a multitude of shells, many broken, and, except *Pholades* and *Cyprinæ*, few bivalves having their valves together. I saw no Boulder Clay beneath; upwards it seemed not sharply defined from the ordinary drift without shells, but yet distinct, so as not to pass gradually into that heterogeneous mass." After alluding to the opinions of Mr. Bean, Mr. S. V. Wood, and Dr. S. P. Woodward as to the age of the deposit, he states that his "own investigations led him to adopt the view that it was a shell-bed as early as the beginning of the Glacial period (possibly pre-glacial), which had been disturbed and displaced bodily by the pressure which attended the boulder-deposits, and not stratified by dispersion under ordinary watery action. This may be expressed by the term *couche remaniée*."

The next writer who speaks from personal knowledge is Dr. Sorby. Describing a section seen about 1852, examined more particularly with a view to obtaining foraminifera, he mentions that "The place where the crag was then best exposed was at the bottom of the cliff, somewhat north of the town. It appeared to me to be a number of small beds of sand and sandy clay amongst the boulder clay of the drift, which occurs both below and above the part with shells, also itself containing many erratic pebbles, like those in the drift. Though some few of the shells are found elsewhere, yet they are most numerous about a quarter of a mile north of the pier. The section there exhibited, at the bottom, bluish grey clay with pebbles of chalk and flint, as well as of other rocks transported from a distance, passing upwards into similar clay without pebbles. Above this was a very variable deposit of sandy beds and clay, similar to that below, as well as some that is brown and quite like the ordinary boulder clay of the district, except in containing shells. Over this were sand and clay, and occasionally pure decomposed chalk, and then a mass of boulder clay of the usual description."

"The lower part of the section is much contorted, in the manner so common in the drift strata It is also well worthy of remark that the same force which produced these contortions appears to have fractured some of the shells imbedded in the clay and displaced the fragments, which, nevertheless, may often be found within a short distance of each other. It seemed as though the exposed crag was only the upper portions of the contortions, and that the main bed was below the level of the beach, and might not have been exposed in the cliff if it had not been thus bent and raised up by lateral pressure."*

In 1864 Mr. Edward Tindall writes that "in January last the tide laid bare about 150 yards of the crag for nearly a fortnight,

* "On the Crag Deposit at Bridlington, and the Microscopic Fossils occurring in it."—*Proc. Geol. Soc. Yorkshire*, vol. iii. p. 559.

and I collected a good series of fossil shells, &c."* This was in answer to the observation of Dr. S. P. Woodward, made upon the authority of Mr. Bean, that "the whole mass has been entirely removed or built over." Mr. Tindall gives no description of the deposit, but Mr. Lamplugh informs me that the section was under Fort Hall, just north of the Parade, and only 50 yards or so from the exposure lately laid bare.

Mr. S. V. Wood, jun., was at Bridlington during the same year, but it would appear from his letter that he confined his attention to the cliffs north of the harbour.† He does not mention having observed any fossils; and it is probable that the Crag noticed by Mr. Tindall was hidden by the sea defences. After looking through all Mr. Wood's later papers I cannot find that any of them contain an account of the Bridlington Crag from personal observations, nor do any other geologists appear to have examined it between the years 1864 and 1878.

After the lapse of 17 years, during which the Crag does not appear to have been observed, Mr. Lamplugh, who had already, in 1874, noticed shell-fragments in the Basement and Purple Clays,‡ rediscovered the deposit close to the original locality. His account thoroughly agrees with that of previous eye-witnesses, but he adds a number of particulars before unrecorded. Among other things he proves that the shelly masses are included in the Basement or lowest Boulder Clay of the coast, and not in any higher bed.

Mr. Lamplugh, from his long residence at Bridlington, has had unequalled opportunities of studying the deposit, and has made excellent use of them. His original descriptions are therefore here quoted; for the observations of the Geological Survey in his particular branch have simply corroborated his results, without adding anything of importance. Many details seen by him were also only visible for a short time before being obscured by talus or the rebuilt sea-wall. The fullest account of the Basement Clay is contained in a paper read by Mr. Lamplugh, before the British Association at York in 1881.§

The wooden defences which protected the cliff opposite the Alexandra Hotel having been removed the autumn before, the section which is described and illustrated was exposed. As this and the other sections will probably before long be entirely hidden behind more substantial walls, the accounts are quoted at considerable length. "In the section opposite the Alexandra Hotel at Bridlington Quay, the Basement Boulder-clay was seen to include several masses of different materials. These masses consisted for the greatest part of a very fine clay, generally either light-blue or dark bluish-black in colour; but in one place brown.

* [Letter on] "The Present State of the Bridlington Crag."—*Geol. Mag.*, vol. i. p. 142.

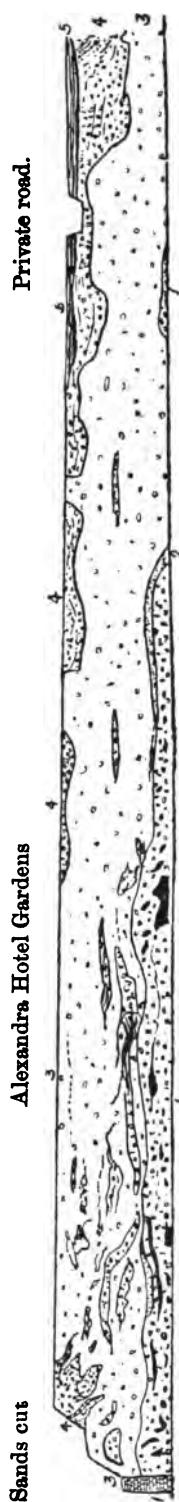
† [Letter on] "The Bridlington Crag."—*Geol. Mag.*, vol. i. p. 216.

‡ *Geol. Mag.*, dec. II. vol. v. p. 509.

§ *Ibid.*, dec. II. vol. viii. p. 537.

FIG. 1.—Cliff opposite the Alexandra Hotel Gardens, Bridlington Quay (G. W. Lamplugh).—(From the Proc. Geol. Soc., West Riding, Yorkshire, n.s., vol. vii. pl. xxix.)

Scale 60 feet to an inch.



- 5 Fresh-water marl, containing many shells and traces of plants.
- 4 Gravel and sand, sometimes contorted into the underlying Boulder Clay.
- 3 Purple Boulder Clay with streaks of sand and small contortions, Shap Granite and other far-transported rocks, and a few shell fragments.
- 2 Dark muddy sand with pebbles (reconstructed Boulder Clay), very impersistent.
- 1 Basement Boulder Clay, dark greenish-blue clay with included masses of shelly sand or clay which yield the fauna of the "Bridlington Crag," (the black masses in the section). Among the far-transported boulders are Felisites, Quartz-porphries, Granites, Basalts, and much Carboniferous Limestone.

This clay seemed to have been a stratified deposit; but the stratification was so nearly destroyed that it was shown merely by irregular stripes. Coarse yellowish-green sand was incorporated with this clay in most of the patches, spreading curiously through their mass in irregular little dabs and threads forming doubtful lines, as though it had been partially kneaded in. This sand always contained many shells, which were generally crushed into fine fragments. Shells also occurred in the clays, but much less plentifully, and often with sand under the valves. The beds contained a few erratic pebbles, chiefly little black phosphatic-looking lumps (which remind me of those in one of the Lower Neocomian beds at Speeton) and a dark green quartzite. I did not notice either chalk or flint in them; in which they differ markedly from those previously described. The largest of these masses was of irregular shape, about 14 feet in its greatest length and four feet in height, and seemed to be crushed vertically between walls of Boulder Clay. From it I obtained the most perfect specimens. The others were much smaller, and were squeezed out so as to form wavy lenticular streaks. The junction between these and the Boulder Clay was sometimes well-marked, and sometimes insensible. After finding a few of the larger shells, I washed lumps of the sand and clay, and obtained thus many small specimens, which were far less broken than the larger, and also many foraminifera and entomostraca, and two or three small echinoid spines. A few, even of the larger shells, were in an absolutely perfect state of preservation; whilst those which were broken were probably broken either during the life of the animal or very shortly after, as in one or two cases the umbos of fragmentary bivalves remained together, though much of the shell was missing; showing, I think, that the ligament existed at the time; and some fragments of *Astarte* and *Cyprina* from Dimlington showed the epidermis.

"I have seen several other patches of this kind in the Basement Boulder-clay, at various times, in exposures on the beach, to the southward of this section,* and nearer the place where the shells were first found, but have not before seen them in section."

"It will be seen that these shelly patches are essentially the same as the so-called 'Bridlington Crag,' which was not really a *bed* at all in the stricter sense of the word, but a similar though more extensive set of streaks and masses of sand and clay in Boulder Clay."

In a postscript Mr. Lamplugh mentions that "the storms of this autumn" (1881) "cleared the shingle from a small extent of beach near the town and close to where the 'crag' was first found. This exposure showed 'Basement Clay' of the usual character, including in it one large mass of clay and sand with shells, and closely adjoining another similar mass of fine dark mud, without shells or stones; and through this there ran a short seam of peaty matter, apparently of vegetable origin. It is not

* *Geol. Mag.*, dec. II. vol. vi. p. 399.

improbable, therefore, that some of these shell-less patches may be of fresh-water origin."*

More recently Mr. Lamplugh has observed a section still closer to the spot where the crag was originally discovered. He mentions that "During the early part of the winter of 1882-3 long continued on-shore gales so far lowered the level of the beach opposite the town of Bridlington Quay, that the sand and shingle was in many places removed, and the Boulder Clay below it well exposed on the foreshore. The largest of these exposures was nearly opposite the place where the shells were first found in the cliff. The Boulder Clay included in it many crushed masses of sand, and sandy gravel, and clay, these forming, indeed, a large proportion, nearly one third, of its bulk."

"The fauna of the masses also varied greatly. Some contained many shells throughout; others very few,—occasionally none; others had shells in one part, but not in another; and one mass seemed to be of freshwater origin, as it consisted of very fine unctuous slaty-blue clay without stones or shells, through which ran a thin seam of peaty matter, in which traces of moss, wood, and the seeds of *Potamogeton* were detected."†

"Shells in Boulder Clay."—The surrounding Boulder-clay also contains many shell-fragments, with now and then a perfect valve, which have undoubtedly been derived from similar beds, having been thoroughly kneaded up and mixed with glacial débris. This is shown by the extremely patchy nature of the clay, even where the shell-beds have been wholly destroyed, as on the south beach at Bridlington, the clay varying in character from step to step."

"Then, too, under many of the unbroken valves, there still remains a little coarse sand, showing the original matrix of the shells;‡ and many of its boulders show *Pholas* and *Cliona* borings; and these borings contain in many instances the same coarse green sand. As not one, but several kinds of rock are bored, the bottom on which the shells lived would seem to have been strewn with boulders."

"As a curious illustration of glacial erosion, I may mention the finding in this Boulder Clay, on the south beach, of a *Tellina baltica* with valves united and perfectly unbroken. Sand filled the interior, but all around was Boulder Clay,—the shell, in fact, occurred as an erratic pebble;—which, I think, shows well how misleading may be the evidence of a few selected specimens as to the general conditions of the bed from which they came; certainly no one would have judged this shell to be from the Boulder-clay."

Near Sands Lane, about a mile north of Bridlington Quay, and not far from the old buried cliff, the Basement Clay first appears on the foreshore; but curiously it is only at the point where the

* *Geol. Mag.*, dec. II, vol. vi, p. 399.

† Lamplugh: "On a Recent Exposure of the Shelly Patches in the Boulder-clay at Bridlington Quay."—*Quart. Journ. Geol. Soc.*, vol. xl, p. 312.

‡ This also occurs in the Till near Cromer.—See *Mem. Geol. Survey, Geology of the Country around Cromer*, p. 86.

sea defences commence that it rises into the cliff, and it again sinks beneath high-water mark south of the town. On the fore-shore Mr. Lamplugh has traced it, with slight intervals, nearly continuously from its first appearance to a point over half a mile south of Bridlington South Pier.* Here it sinks beneath the sea-level, and is not known to reappear till Out Newton, 30 miles further south, is reached. Messrs. Wood and Rome, however, have included in the Basement Clay a bed of very chalky Boulder Clay, seen at several other points, which both Mr. Lamplugh and I consider to belong to the next division. This chalky Boulder Clay appears to pass up into the Lower Purple Clay, but is separated from the Basement Clay by a more or less strongly marked line, or even by stratified beds. From Out Newton and Dimlington the Basement Clay extends continuously, or nearly so, to Kilnsea, where the cliff ends; but no trace of a similar shelly Boulder Clay has yet been found inland, or south of the Humber.

Shells were first noticed at Dimlington by Sir Charles Lyell and Professor Hughes, who, however, do not appear to have attempted to fix their stratigraphical position, though they considered the streak of sand to represent a bed in place. Messrs. Wood and Rome apparently did not observe the shelly clay; they do not mention it, though the overlying chalky clay was traced correctly from Kilnsea to Out Newton. The first to observe and note in detail the shelly Boulder Clay of Dimlington was Mr. Lamplugh, who in the above-quoted paper describes it fully. The subsequent observations of the Geological Survey having only added a few minor particulars, and some additional species to the list of fossils, Mr. Lamplugh's account will be again followed.

“*The Dimlington Shell-beds.*—I have not yet been able to find at Dimlington the bed from which Sir Charles Lyell's party obtained their shells;† but last spring I found streaks, identical in appearance with those at Bridlington, in an exposure of the Basement Clay on the beach a little to the north of the high land. I examined them for shells, and found many, but all crushed. I also got three large hardened casts in gritty sand of *Pholas* borings, with the *Pholas* (*P. crispata*) embedded in the midst. Similar hardened casts are common at Bridlington. About two months ago I again saw an exposure of the Basement Clay at Dimlington,—this time of very unusual extent,—stretching for nearly a mile along the beach near low-water mark. The clay was throughout extraordinarily patchy, and was, in fact, in good part made up of masses of included material, of all sizes, and of diverse composition. Many consisted of fine blue clays mixed with sand, like those of Bridlington; and from these I obtained some very fine and perfect

* “Glacial Sections near Bridlington.” Pts. 1 and 2, *Proc. Geol. Soc. Yorkshire*, n.s., vol. vii. p. 383, and vol. viii. p. 27.

† “In the discussion which followed this paper, Professor Hughes, one of the discoverers, satisfactorily accounted for this, as he said they took the bed away with them, it being merely a curved streak of sand in Boulder Clay like those I have seen.”

shells. Others, however, contained no shells, were almost black in colour, and seemed as if made up of the waste of some of the pyritous secondary clays; for when the sun shone hot upon them they smelt very strongly, and weathered in the cliff with a dirty yellow efflorescence and bad odour, like the lowest beds of the Lower Neocomian at Speeton. They are, indeed, quite possibly made up in part of these beds, as I noticed a few Neocomian fossils in Boulder Clay. Some of the patches, again, were of a rusty brown; and one of these contained a few broken shells, which were possibly derivative."

"I also found in the bottom of the cliff a streak of crushed shells, much in the same position as the one already known. It ran irregularly through a mass of dark-blue clay, without stones, bounded on all sides by Boulder Clay in the same way as those on the beach; the shells, chiefly *Saxicava rugosa*, were crushed into small fragments, and the whole mass showed slickensides. In one or two cases the valves seem to have been united. I found, some time ago, a single specimen of *Tellina balthica*, uncrushed and with valves united, in a little pocket of sand near the same place."

"The Boulder Clay itself was crammed in places with detached and fragmentary valves. It also contained a few huge boulders of far-travelled rocks. One mass of gneiss was about 5 feet by $2\frac{1}{2}$ by 3."

During the months when the neighbourhood of Dimlington was being examined for the Geological Survey, exceptionally good exposures of the Basement Clay were to be seen on the foreshore. One very striking fact, which, though observed before, merits much closer attention, is the common occurrence in the Boulder Clay of boulders of rock crushed, and often rolled out flat. These, seen in vertical section, appear as seams or lenticular masses; sometimes they occur so abundantly and near together as to give a deceptive appearance of bedding to the Boulder Clay. A similar effect is also produced by the crushed seams of shelly clay and sand; but if the Boulder Clay be examined more closely, and on the foreshore, it is seen to be a true unstratified Till.

Among these crushed boulders Oolitic sandstone and Basalts are very common, and several of decomposed Granite were observed. One boulder of sandstone, which must originally have been a yard or more in diameter, had split up into cuboidal masses, the pieces being dispersed over a surface of about twenty square yards. Their appearance reminded one of the fragments of a large flint over which a steam roller has passed, or rather, from the extent of their dispersal, of the crushing of a similar stone under a skidded wheel. The whole character of the Boulder Clay was forcibly suggestive of the action of some heavy sliding weight. Probably the direction from which the force came might have been discovered by taking the direction of the longer axes of these crushed masses: unfortunately this was not thought of when the section was exposed.

Shells are also found in the Boulder Clay, crushed, but with the fragments only separated by a small interval, as already noticed

by Mr. Lamplugh at Bridlington. A perfect specimen of *Tellina obliqua* was discovered, broken in half, and with the angular fragments two inches apart; this has been joined, and is now in the Museum of Practical Geology. Shells with pieces cut out are common both here and at Bridlington. In one case an *Astarte* with the valves united had a notch cut through both valves. Here the ligament would scarcely have been sufficient to prevent the valves separating; and it seems probable that the shell was firmly bedded in ice or frozen mud while the notch was being cut.

Towards Kilnsea, where the cliff becomes very low, the Basement Clay by weathering loses its characteristic colour. If it were not for the perfect continuity of the exposures between Kilnsea and Dimlington, the abundance of shells might be overlooked, and there is no other test by which it could be distinguished from the more recent Boulder Clays.

Except near Dimlington and Bridlington, no exposures of Basement Clay are known in Holderness, but at Selwicks, and in Filey Bay, Mr. Lamplugh has discovered a shelly Boulder Clay of similar character, presumably of the same age.* The correlation of Boulder Clays is, however, always uncertain, and we cannot feel sure that the reference even of the Bridlington and Dimlington beds to the same horizon is proved.

The above description shows that the so-called "Bridlington Crag" consists of masses of shelly sand and clay included in a Boulder Clay. These are evidently as much transported boulders as the adjoining masses of Neocomian Clay or Granite. It is therefore evident that the character of the included fauna cannot be accepted as a test of the age of the bed, or of the conditions under which it was deposited, except so far that the Boulder Clay must be newer than its included boulders. Ice working up the same materials at different periods would produce a Boulder Clay of similar character; and the apparent absence of the Basement Clay inland may only be the result of the deposition of all the shelly masses within a short distance of their place of origin. The only safe test for the correlation of glacial deposits, where the sections are not continuous, is apparently the character of the fauna and flora found in the associated stratified beds.

Where the shelly masses in the Basement Clay come from is still uncertain; probably they have not travelled far, and were ploughed up by the ice from the bed of the North Sea, within a short distance of the present shore. Amongst other boulders we have abundance of Speeton Clay, occasional pudding-stone, and green-coated flints, probably derived from Eocene beds, black flints of a character unknown in the Yorkshire Chalk, Oolitic Sandstone, Carboniferous Limestone, Basalt, Granite, Gneiss, and numerous far-transported rocks of undetermined origin. The local chalk and flint are not nearly so abundant as one would expect, or as they are in newer Boulder Clays. Shap Granite

* "On the Divisions of the Glacial Beds in Filey Bay."—*Proc. Geol. Soc. Yorkshire*, n. s., vol. vii. p. 167.

has not yet been found in place in the Basement Clay, though it occurs not uncommonly scattered over the northern half of Holderness. A large boulder, measuring $3 \times 2\frac{1}{2} \times 2$ feet, lies on the foreshore at extreme low-water mark at Out Newton, near Dillington, resting on the Basement Clay, but there is nothing to show from which of the Boulder Clays it was derived. This appears to be the furthest point to which Shap Granite has been traced in a south-easterly direction.

Mr. Lamplugh has lately presented to the Geological Survey a collection of stones obtained from the Basement Clay at Bridlington. Except the Secondary Rocks, which certainly belong to the North Yorkshire type, probably continued under the North Sea, few of these can yet be recognized as coming from any particular district. The Director General, who has examined the specimens, thinks that the granites, gneisses, mica, and other schists and quartzites almost certainly come from Scandinavia. The eruptive rocks may have travelled from the same source, or from some area now submerged under the North Sea. Among them, however, are various diabases and amygdaloidal porphyrites which greatly resemble the rocks of the Old Red Sandstone and Carboniferous volcanic series in the Cheviot Hills and eastern Berwickshire.

Mr. Lamplugh's collection includes:—

Fragments of Arctic mollusca ("Bridlington Crag").

Green-coated flints (Eocene?).

Soft Chalk and black flint (not local).

Hard Chalk (often bored by annelids), and grey flints with *Inoceramus* (probably local).

Red flints (Danish?).

Fossiliferous shale (Speeton Clay).

Septaria.

Oolitic Limestone.

Earthy Limestone.

Calcareous Grit.

Estuarine Sandstone (Lower Oolite of Yorkshire?).

Jet Rock, some fragments with *Inoceramus dubius*. } Upper Lias of *Ammonites communis*. } Yorkshire.

Hard Shale with *Avicula*.

Sandy Shale.

Cleveland Ironstone.

Belemnites, sp.

Lima.

Pentacrinus.

Amonites Jamesoni?

— *bifrons*.

— *Brookii*.

— *semicostatus*.

Gryphaea arcuata.

Cardinia Listeri.

Carboniferous Limestone and Chert. }

— Sandstone.

Grits, Conglomerates, and Breccias.

Vein Quartz.

Jasper (pebbles).

Quartzite of various colours (usually well rounded, and probably derived from old Conglomerates).

Arkose.

Mica Schist (some garnetiferous).

Gneiss.

Hornblende Schist.

Diorite.

Syenite.

Hornblendic Granite.

Granite and Granitoid Rocks of many varieties.

Quartz Felsite.

Various Porphyrites, often amygdaloidal (of the Cheviot type).

Basalt (fine grained and amygdaloidal).

Diabase with large Olivine.

Diabase, fine grained porphyritic (like some of the Old Red Lavae).

Volcanic Tuff.

The fauna of the shelly masses included in the Basement Clay is of great interest, and has attracted attention ever since the deposit was first discovered. As the age of this so-called "Crag" has been much disputed, an outline will be given of the different opinions which have finally led to the conclusion that the fauna presents a thoroughly Arctic facies, and belongs to the Pleistocene period. Though each mass shows some slight peculiarity in the distribution of the included mollusca, or perhaps may contain a form unknown in the others, yet the general facies of the fauna is so uniform that the different masses may safely be accepted as representing the broken-up remains of one bed, or of a series of beds, deposited under similar conditions and during one period.

Professor Sedgwick's original reference of the fossils to an Eocene bed is accounted for by the unfortunate destruction of his specimens before they could be determined. The matrix is remarkably like some of the Lower Eocene beds of the London basin, and the green-coated flints perhaps show that it is partly formed from the destruction of an underlying bed of Eocene age.

On the re-discovery of the bed in 1835, Mr. Bean obtained fresh specimens, from which, believing that more than half of them could not be referred to any existing species, he spoke of the shells as coeval with, if not of higher antiquity than, the Crag. Shortly after, Sir Charles Lyell received from Mr. Bean a series of the shells, and concluded that 20 out of the 35 were recent species. The general similarity of the fauna, and the occurrence of *Nucula Cobboldiae*, led him to correlate the Bridlington bed with the Norwich Crag.*

This determination was also accepted by Mr. S. V. Wood, in the Crag Mollusca; and by Edward Forbes, who writes, "The examination of the Bridlington fossils has convinced me that they are truly of the age of the mammiferous crag, and that both those formations may be referred to the epoch of the Northern Drift, and probably—especially the last-mentioned—to the commencement of that epoch before the severer conditions had set in."† It is evident that Edward Forbes suspected that the Bridlington Crag might turn out to be newer than the Norwich Crag.

Here the question remained till 1864, when Dr. S. P. Woodward, working with much larger collections from Bridlington, and

* Lyell: "On the relative Ages of the Tertiary Deposits commonly called 'Crag,' in the Counties of Norfolk and Suffolk."—*Mag. Nat. Hist.*, vol. xii. p. 324, 1839.

† *Mem. Geol. Survey*, vol. i. p. 392, 1846.

with fuller information as to the living Arctic mollusca, was able to state that "This investigation has led to the somewhat unexpected result that the Bridlington deposit can no longer be considered the exact equivalent of the Norwich Crag in age, or in climatical conditions. Of the 63 shells found by Mr. Leckenby and Mr. Bean at Bridlington, only 35 are common to the Norwich Crag. And while 29 species, or one-half of those from Bridlington which are still living, are limited to the seas north of Britain, only one-sixth part of those found in the Norwich Crag have an Arctic character."* Subsequent discoveries have only tended to confirm and strengthen this conclusion.

Mr. S. V. Wood, and Mr. S. V. Wood, junior, afterwards tried to fix the exact position of the Bridlington Crag in the Glacial Deposits, principally by the proportion of extinct mollusca. They considered the fauna to be newer than that of the Middle Glacial Sands of Norfolk, and to belong to the upper portion of the overlying Great Chalky Boulder Clay.† This correlation will be again referred to.

Quite recently the researches of Messrs. Lamplugh and Headley have resulted in the collection of a very large amount of fresh material. This enabled Dr. Gwyn Jeffreys, who had already examined the old collections, and revised the lists for Professor Phillips' Geology of Yorkshire, to add upwards of 30 species of mollusca, raising the total number to over 100, excluding varieties. Of these Dr. Jeffreys describes five as new; and, besides those recognised by him as extinct, five others are also so treated in Mr. S. V. Wood's lists. One of them, *Trophon Leckenbyi*, has since been found living in deep water between Shetland and the Faroe Islands; *Nucula Cobboldiae* is considered by Dr. Jeffreys to be a variety of a living species, *N. insignis* of Japan; *Tellina obliqua* is referred to an extinct variety of *T. calcaria*; and two forms of *Pleurotoma*, *P. Dowsoni*, and *P. robusta* are referred respectively to the living species *P. turricula* and *P. harpularia*.

Of the 99 living species, 47 are exclusively Arctic; and, besides these particularly Arctic species, 41 of the littoral forms are also Arctic, making the total number of the latter 88 or about 87 per cent. of the whole. Thus the molluscan fauna of the Bridlington Crag is of an intensely Arctic character; in fact, is more markedly boreal than that of any other British deposit. The species recently added to the list by Dr. Gwyn Jeffreys being mostly Arctic forms, and many of them exclusively Arctic, this result has been brought out even more clearly than before. A few of the living forms, including *Fusus curtus*, *Pleurotoma bicarinata*, *P. decussata*, and *Turritella erosa*, are at the present day confined to American seas, but the fauna does not include a single species which has an exclusively southern range.

* S. P. Woodward: "Remarks on the Bridlington Crag, with a list of its Fossil shells."—*Geol. Mag.*, vol. i. p. 49.

† S. V. Wood, Suppt. to the Crag Mollusca; and S. V. Wood, jun., *Quart. Journ. Geol. Soc.*, vol. xxvi. p. 90.

The depth at which the Bridlington Crag fauna flourished does not seem quite clear, for Dr. Jeffreys considers the shells found at Dimlington comparatively shallow water species, from 2 to 10 fathoms ; while Mr. H. B. Brady remarks on 17 species of Foraminifera from the same locality that "the fauna appears to represent a somewhat colder area than the Bridlington Crag, as far as I have information of the latter. This collection appears to indicate a cold bottom of *not less* than 40 *nor above* 80 fathoms."

This apparent discrepancy may be partly due to the well-known fact that the vertical range of many species is largely determined by temperature. A fauna which lives in shallow water in the Arctic regions may thus be confined to greater depths further south. Another disturbing cause is the action of shore ice, of which we seem to have good evidence in the far-transported stones in the shelly clay. This ice would continually carry away littoral shells, and drop them into deeper water, while it could never bring deep-water forms to mix with the littoral. Thus a deceptive littoral facies might be given to the fauna, though the species which actually lived together were all of them forms needing a depth of several fathoms. The general impression which an examination of the whole of the evidence leaves is that the Bridlington Crag was originally deposited in somewhat deeper water than the list of shells alone would appear to show. The depth may have been 20 to 40 fathoms, or perhaps even more.

In the subjoined lists the Bridlington Foraminifera are taken from the Palaeontographical Society's Monograph, by Messrs. Jones, Parker, and Brady, with the addition of other species lately obtained by Mr. Lamplugh, and determined by Dr. W. H. Crosskey, and Mr. H. B. Brady, F.R.S. The Dimlington species were collected in the course of the Geological Survey, and determined by Mr. H. B. Brady, F.R.S. The Bridlington Entomostraca are from the same sources, and have been determined by Messrs. G. S. Brady, Crosskey, and Robertson ; those from Dimlington were obtained by the Geological Survey, and determined by Dr. G. S. Brady, F.R.S. The revised lists of Dr. Gwyn Jeffreys contained in the last edition of Prof. Phillips' Geology of Yorkshire, and in Mr. Lamplugh's papers, have been used for the Bridlington Mollusca ; the smaller list from Dimlington contains the species found by Mr. Lamplugh and the Geological Survey. The vertebrates are taken from Mr. Lamplugh's last paper, and were named by Mr. E. T. Newton. Most of them are probably derivative.

The comparatively small list from Dimlington is entirely due to the imperfect search made at that place ; when properly examined it will probably yield as many species as Bridlington. To obtain the smaller species of mollusca it is necessary to wash a considerable amount of the clay or sand from different masses. The assemblage is not quite the same in all of them, and if attention is confined to one mass many of the species will be overlooked.

	Bridlington.	Dimlington.	Remarks.
PLANTÆ.			
Potamogeton, <i>sp.</i> - - -	x	.	See p. 14.
FORAMINIFERA.			
Biloculina elongata, <i>D'Orb.</i> -	x	.	
— ringens, <i>Lam.</i> -	x	x	
Bulimina marginata, <i>D'Orb.</i> -	.	x	
Cassidulina crassa, <i>D'Orb.</i> -	x	x	
— lavigata, <i>D'Orb.</i> -	x	x	
Cornuspira foliacea, <i>Ph.</i> -	x	.	
Cristellaria cultrata, <i>Mont.</i> -	x	.	
— acutauricularis, <i>F. & M.</i> -	.	x	
Dentalina brevis, <i>D'Orb.</i> -	x	.	
— communis, <i>D'Orb.</i> -	x	x	
— pauperata, <i>D'Orb.</i> -	x	.	
Gaudrynia pupoides, <i>D'Orb.</i> -	x	.	
Glandulina lavigata, <i>D'Orb.</i> -	x	.	
— var. rotundata -	x	.	
— aequalis -	x	.	
Globigerina bulloides, <i>D'Orb.</i> -	.	x	
Lagenia globosa, <i>Mont.</i> -	x	.	
— lavigata, <i>Reuss.</i> -	x	.	
— lavis, <i>Mont.</i> -	x	.	
— squamosa, <i>Mont.</i> -	x	.	
— sulcata, <i>W. & J.</i> -	x	.	
Miliolina seminulum, <i>L.</i> -	x	x	
— oblonga, <i>Mont.</i> -	.	x	
Nonionina depressula, <i>W. & J.</i> -	x	x	
— orbicularis? <i>Brady</i> -	x	.	
— scapha, <i>F. & M.</i> -	x	.	
Polymorphina compressa, <i>D'Orb.</i> -	x	.	
— lactea, <i>W. & J.</i> -	x	x	
— lanceolata, <i>Reuss.</i> -	.	x	
— Thouini, <i>D'Orb.</i> -	x	.	
Polystomella crista, <i>L.</i> -	.	x	
— striato-punctata, <i>F. & M.</i> -	x	x	
Pulvinulina Karsteni, <i>Reuss.</i> -	x	.	
Quinqueloculina seminulum, <i>L.</i> -	x	.	
— triangularis, <i>D'Orb.</i> -	x	.	
Rotalia Beccarii, <i>L.</i> -	.	x	
Triloculina oblonga, <i>Mont.</i> -	x	.	
Truncatulina lobatula, <i>W. & J.</i> -	x	x	
Uvigerina angulosa, <i>Williamson</i> -	.	x	
Vaginulina lavigata, <i>Roemer</i> -	x	.	
— legumen, <i>L.</i> -	x	.	
ECHINODERMATA.			
Undetermined spines, &c. -	x	x	Much broken.
CIRRIPEDIA.			
Balanus crenatus, <i>Brug.</i> -	x	x	
— Hameri, <i>Asc.</i> -	x	x	Northern.
— porcatus, <i>Da C.</i> -	x	x	
Verruca Strömia, <i>Müll.</i> -	x	.	

	Bridlington.	Dinlington.	Remarks.
ENTOMOSTRACA.			
<i>Cythere angulata</i> , <i>G. O. Sars.</i> -	x	.	
— <i>concinna</i> , <i>Jones</i> -	x	x	
— <i>costata</i> , <i>Brady</i> -	x	.	
— <i>cribrosa</i> , <i>B., C. & R.</i> -	x	.	
— <i>dunelmensis</i> , <i>Norman</i> -	x	x	
— <i>emarginata</i> , <i>G. O. Sars.</i> -	x	.	
— <i>fimbriata</i> , <i>Norman</i> -	x	.	
— <i>globulifera</i> , <i>Brady</i> -	x	.	
— <i>Jonesii</i> , <i>Baird</i> , var. <i>cera-</i> <i>toptera</i> . -	.	x	
— <i>leioderma</i> , <i>Norman</i> -	x	.	
— <i>McCheaneyi</i> , <i>B. & C.</i> -	x	.	
— <i>mirabilis</i> , <i>Brady</i> -	x	.	
— <i>tuberculata</i> , <i>G. O. Sars.</i> -	x	x	
— <i>villosa</i> , <i>G. O. Sars.</i> -	x	.	
<i>Cytheridea elongata</i> , <i>Brady</i> -	x	.	
— <i>papillosa</i> , <i>Bosquet</i> -	x	.	
— <i>punctillata</i> , <i>Brady</i> -	x	x	
— <i>sorbyana</i> , <i>Jones</i> -	x	x	
<i>Cytheropteron angulatum</i> , <i>B. & R.</i> -	x	.	
— <i>latissimum</i> , <i>Norman</i> -	x	x	
— <i>nodosum</i> , <i>Brady</i> -	x	.	
<i>Cytherura clathrata</i> , <i>G. O. Sars.</i> -	x	.	
<i>Eucythere argus</i> , <i>G. O. Sars.</i> -	x	.	
<i>Krithe glacialis</i> , <i>B., C. & R.</i> -	x	x	
<i>Paradoxostoma ensiforme</i> , <i>Brady</i> -	x	.	
— <i>pyriforme</i> , <i>B., C. & R.</i> -	x	.	
<i>Sclerochilus contortus</i> , <i>Norman</i> -	x	.	
POLYZOA.			
<i>Undetermined</i> -	x	.	
BRACHIOPODA.			
<i>Rhynchonella psittacea</i> , <i>Chemn.</i> -	x	.	A.
CONCHIFERA.			
<i>Anomia ephippium</i> , <i>L.</i> -	x	.	L. and A.
— var. <i>aculeata</i> -	x	.	L. and A.
— <i>squamula</i> -	x	.	L. and A.
<i>Astarte borealis</i> , <i>Chemn.</i> -	x	x	A.
— var. <i>mutable</i> -	x	.	A.
— <i>Withami</i> -	x	x	A.
— <i>compressa</i> , <i>Mont.</i> -	x	x	L. and A.
— var. <i>striata</i> -	x	.	L. and A.
— <i>depressa</i> , <i>Brown</i> -	x	x	A. A. <i>crebricostata</i> , <i>Forbes</i> .
— <i>sulcata</i> , <i>Da C.</i> -	x	.	L. and A.
— var. <i>elliptica</i> -	x	x	L. and A.
<i>Axinopsis orbiculata</i> , <i>G. O. Sars.</i> -	x	.	A.
<i>Cardita borealis</i> , <i>Conrad</i> -	x	.	A.
<i>Cardium echinatum</i> , <i>L.</i> -	.	?	L. and A.
— <i>edule</i> , <i>L.</i> -	x	x	L.
— <i>groenlandicum</i> , <i>Chemn.</i> -	x	x	A.
— <i>islandicum</i> , <i>L.</i> -	x	x	A.
<i>Corbula gibba</i> , <i>Oliv.</i> -	x	.	L. and A. C. <i>striata</i> , <i>W. and B.</i>

	Bridlington.	Dinlington.	Remarks.
<i>Corbula pusilla</i> , <i>Philippi</i> . -	- x	.	L. and A.
<i>Crenella decussata</i> , <i>Mont.</i> -	- x	.	L. and A.
<i>Cyprina islandica</i> , <i>L.</i> -	- x	x	L. and A.
<i>Donax vittatus</i> , <i>Da C.</i> -	- x	.	L.
<i>Leda intermedia</i> , <i>M. Sars.</i> -	- x	.	A.
— <i>lenticula</i> , <i>Müll.</i> -	- x	.	A.
— <i>limatula</i> , <i>Say.</i> -	- x	.	A. <i>L. oblongoides</i> , <i>S. V. Wood.</i>
— <i>minuta</i> , <i>Müll.</i> -	- x	.	L. and A. <i>L. caudata</i> , <i>Donovan.</i>
— — — <i>var. buccata</i> -	- x	.	
— <i>pernula</i> , <i>Müll.</i> -	- x	x	A.
— <i>tenuis</i> -	- x	.	L. and A.
<i>Lutraria elliptica</i> , <i>Lam.</i> -	- .	.	Basement clay at Filey.
<i>Mactra solida</i> , <i>L.</i> , <i>var. elliptica</i> -	- x	x	L. and A.
<i>Montacuta Dawsoni</i> , <i>Jeffreys</i> -	- x	.	A.
<i>Mya arenaria</i> , <i>L.</i> -	- ?	.	L. and A.
— <i>truncata</i> , <i>L.</i> -	- x	x	L. and A.
— — — <i>var. uddevalensis</i> -	- x	.	A.
<i>Mytilus edulis</i> , <i>L.</i> -	- x	.	L. and A.
— <i>modiolus</i> , <i>L.</i> -	- x	x	L.
<i>Nucula Cobboldiæ</i> , <i>Leathes</i> -	- x	x	N. <i>insignis</i> ? <i>Gould</i> , or extinct?
— <i>tenuis</i> , <i>Mont.</i> -	- x	.	L. and A.
— — — <i>var. inflata</i> -	- x	.	L. and A.
— <i>nucleus</i> , <i>L.</i> -	- x	.	L. and A.
<i>Pecten islandicus</i> , <i>Müller</i> -	- x	x	A.
— <i>opercularis</i> , <i>L.</i> -	- x	.	L. and A.
— <i>pes-lutræ</i> , <i>L.</i> -	- x	.	L. and A.
<i>Pectunculus glycymeris</i> , <i>L.</i> -	- x	.	L. and A.
<i>Pholas crispata</i> , <i>L.</i> -	- x	x	L. and A.
<i>Saxicava norvegica</i> , <i>Spengler</i> -	- x	x	L. and A.
— <i>rugosa</i> , <i>L.</i> -	- x	x	L. and A. <i>S. arctica</i> , <i>L. var.</i>
<i>Solen ensis</i> , <i>L.</i> -	- .	.	L. and A.
<i>Tellina balthica</i> , <i>L.</i> -	- x	x	L. and A. <i>T. solidula</i> , <i>Pulteney.</i>
— <i>calcaria</i> , <i>Chemn.</i> -	- x	x	A. <i>T. lata</i> , <i>Gmel.</i> <i>T. proxima</i> , <i>Brown.</i>
— <i>obliqua</i> , <i>J. Sow.</i> -	- x	x	Extinct?
— <i>pusilla</i> , <i>Philippi.</i> -	- x	.	L. and A.
<i>Thracia prætenuis</i> , <i>Pult.</i> -	- x	.	L.
— <i>pubescens</i> , <i>Pult.</i> -	- x	x	L.
<i>Venus fluctuosa</i> , <i>Gould</i> -	- x	.	A.
— <i>ovata</i> , <i>Pennant</i> -	- x	.	L. & A.
SOLENOCONCHIA.			
<i>Dentalium entalis</i> , <i>L.</i> -	- x	x	L. and A.
— — — <i>striolatum</i> , <i>Stimpson</i> -	- x	x	L. & A. <i>D. abyssorum</i> , <i>Sars.</i>
GASTROPODA.			
<i>Admete viridula</i> , <i>Fabr.</i> -	- x	.	A.
<i>Amaura sulcosa</i> , <i>Leche</i> -	- x	.	A.
<i>Buccinum grönlandicum</i> , <i>Chemn.</i> -	- x	.	A.
— <i>undatum</i> , <i>L.</i> -	- x	x	L. and A.
<i>Bulla crebristriata</i> , <i>Jeffr.</i> -	- x	.	Extinct.
<i>Columbella rosacea</i> , <i>Gould</i> -	- x	.	A. <i>C. Holbœllii</i> , <i>Bect.</i>
— <i>alba</i> , <i>Brown</i> -	- x	.	A.
— <i>sculpta</i> , <i>Leche</i> -	- x	.	A.

	Bridlington.	Dinlington.	Remarks.
<i>Fusus curtus</i> , <i>Jeffr.</i> -	x	.	American.
— <i>var. expansa</i> -	x	.	American.
— <i>despectus</i> , <i>L.</i> -	x	x	A.
— <i>Kroyeri</i> , <i>Möll.</i> -	x	.	A.
— <i>Leekenbyi</i> , <i>S. V. Wood</i> -	x	.	Deep water between Shetland and the Faroe I.
— <i>propinquus</i> , <i>Alder</i> -	x	.	A.
— <i>Sarsi</i> , <i>Jeffr.</i> -	x	.	A.
— <i>spitzbergensis</i> , <i>Reeve</i> -	x	x	A.
<i>Lacuna divaricata</i> , <i>Fabr.</i> -	x	.	L. and A. <i>L. vincta</i> , <i>Mons.</i>
<i>Lepeta cæca</i> , <i>Müll.</i> -	x	.	A.
<i>Littorina globosa</i> , <i>Jeffr.</i> -	x	.	Extinct.
— <i>littorea</i> , <i>L.</i> -	x	x	L. and A.
— <i>obtusata</i> , <i>L.</i> -	x	.	L. and A.
— <i>var.</i> -	x	.	L. and A.
— <i>rudis</i> , <i>Maton.</i> -	x	.	L. and A.
<i>Menestho albula</i> , <i>Fab.</i> -	x	.	A.
<i>Natica affinis</i> , <i>Gmel.</i> -	x	x	A. <i>N. clausa</i> , <i>B.</i> and <i>S.</i>
— <i>var. occlusa</i> -	x	.	A.
— <i>grœnlandica</i> , <i>Beck</i> -	x	.	A.
— <i>islandica</i> , <i>Gmel.</i> -	x	x	A. <i>N. helicoides</i> , <i>Johnston.</i>
— <i>Montacuti</i> , <i>Forbes</i> -	x	.	L. and A.
<i>Odostomia conspicua</i> , <i>Alder</i> -	x	.	L.
<i>Pleurotoma bicarinata</i> , <i>Couth.</i> -	x	.	A. American.
— <i>var. violacea</i>	x	.	A. American.
— <i>decussata</i> , <i>Couth.</i> -	x	.	A. American.
— <i>var.</i> -	x	.	A.
— <i>elegans</i> , <i>Möll.</i> -	x	.	A.
— <i>exarata</i> , <i>Möll.</i> -	x	.	A.
— <i>harpularia</i> , <i>Couth.</i> -	x	.	A. <i>P. robusta</i> , <i>S. V. Wood.</i>
— <i>multistriata</i> , <i>Jeffr.</i> -	x	.	Extinct.
— <i>pyramidalis</i> , <i>Str.</i> -	x	x	A.
— <i>simplex</i> , <i>Midd.</i> -	x	.	A.
— <i>trevelyana</i> , <i>Turt.</i> -	x	.	A.
— <i>turricula</i> , <i>Mont.</i> -	x	x	L. and A.
— <i>var. Dowsoni</i>	x	.	.
<i>Puncturella Noachina</i> , <i>L.</i> -	x	.	L. and A.
<i>Purpura lapillus</i> , <i>L.</i> -	x	.	L. and A.
<i>Rissoa subperforata</i> , <i>Jeffr.</i> * -	x	.	Extinct.
— <i>parva</i> , <i>Da Costa</i> -	x	.	L. and A.
— <i>Wyville-Thomsoni</i> , <i>Jeffr.</i> -	x	.	Deep water.
— <i>var.</i> -	x	.	.
<i>Scalaria grœnlandica</i> , <i>Chenn.</i> -	x	x	A.
<i>Trichotropis borealis</i> , <i>B. & S.</i> -	x	.	L. and A.
<i>Trochus cinereus</i> , <i>Couth</i> -	x	.	A.
— <i>cinerarius</i> , <i>L.</i> -	x	.	L. and A.
— <i>grœnlandicus</i> , <i>Chenn.</i> -	x	.	L. and A.
— <i>varicosus</i> , <i>M. & A.</i> -	x	.	A. <i>Margarita elegantissima</i> , <i>Bean.</i>
— <i>zizyphinus</i> , <i>L.</i> -	x	.	L. and A.
<i>Trophon clathratus</i> , <i>L.</i> -	x	.	A. <i>T. scalariformis</i> , <i>Gould.</i>
— <i>var. Gunneri</i> -	x	.	A.
— <i>truncata</i> -	x	.	A. <i>T. Bamflius</i> , <i>Don.</i>
— <i>Fabricii</i> , <i>Beck</i> -	x	.	A.
— <i>latericeus</i> , <i>Müll.</i> -	x	.	A.
<i>Turritella erosa</i> , <i>Couth.</i> -	x	x	A. American.

* *Rissoa costata* and *R. semistriata* were also found by Mr. Headley, but Dr. Jeffreys thinks they may be recent specimens; they look extremely recent, and the clay was obtained between tide marks.

	Bridlington.	Dinlington.	Remarks.
<i>Turritella terebra, L.</i>	x	x	
<i>Utriculus constrictus, Jeffr.</i>	x	.	Extinct.
<i>obtusus, Mont., var. per-</i>			
<i>tenuis</i>	x	.	A.
VERTEBRATA (probably all derivative from Crag, Eocene, or older rocks).			
<i>Carcharodon</i> (teeth), and other sharks	x	.	
<i>Chrysophrys</i> (teeth)	x	.	
<i>Lamna subulata, Ag.</i> (teeth)	x	.	
<i>sp.</i>	x	.	
<i>Myliobatis</i> (teeth)	x	.	
<i>Notidamus microdon, Ag.</i> (teeth)	x	.	
<i>Oxyrhina</i> (teeth)	x	.	
<i>Platax Woodwardi?</i> <i>Ag.</i>	x	.	
<i>Raia batis, Mont.</i> (teeth)	x	.	
Otoliths of Gadoid fish	x	.	
Fish vertebrae	x	.	
<i>Plesiosaurus</i>	x	.	
Ruminant, fragment of tooth	x	.	
<i>Ursus, sp.</i>	x	.	In Mr. Bedwell's collection.

A = Arctic.

L = Littoral or shallow water, i.e. less than 100 fathoms.

CHAPTER III.

BOULDER CLAY—*continued.*

The next division, the Lower Purple, is of less interest than the Basement Clay, and its differences from that Boulder Clay are principally negative. It does not contain the broken-up masses of shelly beds, so characteristic of the Basement Clay; and the shell fragments among its boulders are also much less abundant and perfect. It is a tough, occasionally streaky, lead-coloured, or bluish-purple Boulder Clay, generally very chalky near the base, but with less Chalk in the upper part. Hard striated boulders are more abundant in it than in the Basement Clay, and perhaps more varied; but if the soft boulders of the Basement Clay are taken into account, the proportion of recognizable far-transported rocks will probably be about the same in each.

The bulk of the material in all the Holderness Boulder Clays has evidently been brought from a distance, though the character of the upper ones suggests that they may have been formed in two ways;—either by a more complete grinding-up, weathering, and

mixture of the same materials that produced the Basement Clay, or more simply by the destruction and ploughing-up of that Boulder Clay, and the mixture with it of a considerable proportion of the local chalk and flint. Either view would account for the occurrence, in a more fragmentary state, of the same species of mollusca and the same boulders as are found in the Basement Clay. At present we cannot say that any of the far-transported rocks are confined to the higher divisions, though Shap Granite is at any rate more abundant in the Purple Clay, and may be entirely wanting in the Basement Clay.

The Upper Purple Clay is very similar to the lower, but contains few shell fragments. It is generally divided from the Lower by a red band about a foot thick, consisting of obscurely stratified Boulder Clay material. Sometimes, however, this red band is replaced by a few feet of gravel, the stones of which appear to have been derived from the underlying Lower Purple Clay.

Above the Upper Purple Clay there is another line of division, more commonly marked by stratified gravels; and upon this rests a fourth Boulder Clay, correlated by Mr. S. V. Wood, jun., with the Boulder Clay of Hessle. This clay, when unweathered, is quite undistinguishable in lithological character or colour from the lower ones, though boulders seem generally smaller and less abundant, and shell fragments, already very rare in the upper part of the Purple Boulder Clay, have not yet been found in it.

These three Boulder Clays are so much alike, that without continuous sections it is impossible to say to which division an isolated exposure belongs. All the Boulder Clays seen in the cliff above the Basement Clay will therefore be described together, commencing at Flamborough; and where the tracing of the different horizons seems safe, the probable equivalents will be indicated. The inland sections will afterwards be mentioned; but in this case there is nothing whatever to go upon in the correlation of the Boulder Clays, except the fact of their lying over or under a fossiliferous horizon, which horizon unfortunately cannot yet be recognized on the coast.

In the narrow valleys which cut deep into the Chalk near Flamborough, the Boulder Clay, as is usual in hilly districts, splits up into a large number of beds separated by gravels. Similar divisions in valley Boulder Clays are often taken to prove inter-glacial periods, but it seems more probable that most of them only mark the position of sub-glacial watercourses. Sub-glacial rivers are always to be found under the glaciers of the Alps, and they form one of the most curious features in the glaciation of Greenland. In a hill country we should naturally expect to find these gravels abundant in the valleys, while in flat districts like the plain of Holderness the Boulder Clay seems to have been deposited more continuously, and there are fewer divisions.

Another common distinction between the glacial deposits of a hill country and of a plain is the curious way in which Boulder Clays deposited on uneven ground seem to pass laterally into clayey gravels, or even into clean eskar-like gravels. This is very clearly

brought out by Mr. Dakyns' description of the Drifts lying on the Chalk near Flamborough, from which the following account is principally taken. But the phenomenon is not confined to this area; it is very common along the whole of the hilly part of the Yorkshire coast north of Flamborough, and also in other hilly districts in England. In the North Yorkshire Moors it was one of the greatest hindrances to the accurate mapping of the deposits; for, even with a perfectly clear section, it was often impossible to say whether a certain bed ought to be called a gravelly Boulder Clay, or a clayey Gravel. This is also probably connected with the sub-glacial flow of water.

Boulder Clay stretches continuously over the sea-ward end of the Wolds, from Bridlington to the Chalk escarpment; but over the very highest cliffs the topmost Boulder Clay seems often to be alone present. It often becomes so stony that it is hard to say whether it should be called Gravel or Boulder Clay. And, quite in keeping with this, we find that mounds of gravel when traced to the cliff edge seem to end in this earthy Boulder Clay. Thus the gravel mounds stretching from Speeton along the top of the Chalk escarpment pass into Boulder Clay, as far as one can judge in the absence of perfectly clear sections.*

It may be advisable to point out at once that the shells in these gravelly Boulder Clays and Gravels of Flamborough are all, as far as yet known, Basement Clay species: no trace has yet been found of a contemporaneous fauna such as might have lived among the stones. The shelly sand at Speeton, which will be referred to again in Chapter V., is at a much lower level, and contains a quite different fauna.

At the extreme easterly point of Flamborough Head, at High Stacks, the Boulder Clay is in four divisions. The section given by Mr. Dakyns is as follows:—

- Rèd Boulder Clay.
- Chalky Gravel.
- Boulder Clay.
- Chalky Gravel.
- Boulder Clay.
- Gravel.
- Purple Boulder Clay.

In Danes Dike Valley the sections are still more complicated and very variable. Mr. Dakyns describes the beds seen on the west side, when fully developed, as consisting of the following members:—

- Bedded Gravel of Drift Pebbles.
- Boulder Clay, 6 feet.
- Chalky Gravel, 7 feet.
- Boulder Clay.
- Sand.
- Boulder Clay.
- Sand and Gravel.
- Chalky Gravel, well-bedded, thining out rapidly eastwards.

* See J. R. Dakyns' "Glacial Deposits North of Bridlington."—*Proc. Geol. Soc. Yorkshire*, n.s., vol. vii. p. 251.

Boulder Clay.

Angular Chalk débris and Gravel, which dies out east of the valley.

Boulder Clay.

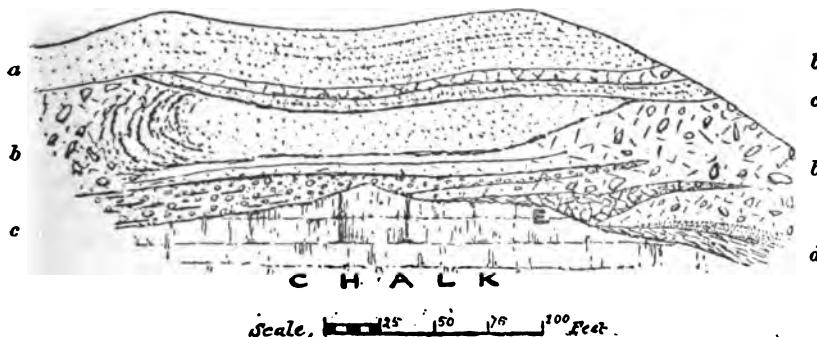
Sand, about 6 feet.

Fine Chalk-wash, in twisted laminae, about 6 feet.

Chalk.

The lowest bed is, like the chalky rain-wash, probably due to sub-aërial denudation or weathering, which is apt to clothe with angular débris the bottoms and sides of valleys in the Chalk. The higher sand-bed ends abruptly under Boulder Clay on the west; it is not a well-bedded sand, but its layers seem to be twisted back under the Boulder Clay, from west to east. A diagram by Mr. Dakyns is given of the mode of occurrence of the beds, most of which appear to be very impersistent even in a short section.

FIG. 2.—Section on the west side of the Danes Dike Valley.



Owing to the thinning out of the other beds, the section on the east side of the valley consists of the following members alone:—

Gravel.

Boulder Clay.

Chalky Gravel.

Boulder Clay.

Sand.

Chalk-wash.

Chalk.

About 200 yards up the valley, the details of the section are quite different:—

	FEET.
Fine Chalk Gravel.	4
Boulder Clay	25
Coarse irregular Chalk Gravel	7
Chalk-wash or fine stratified Chalk Gravel	—
Boulder Clay, containing chiefly small Chalk fragments, a few foreigners, and a little sand	20

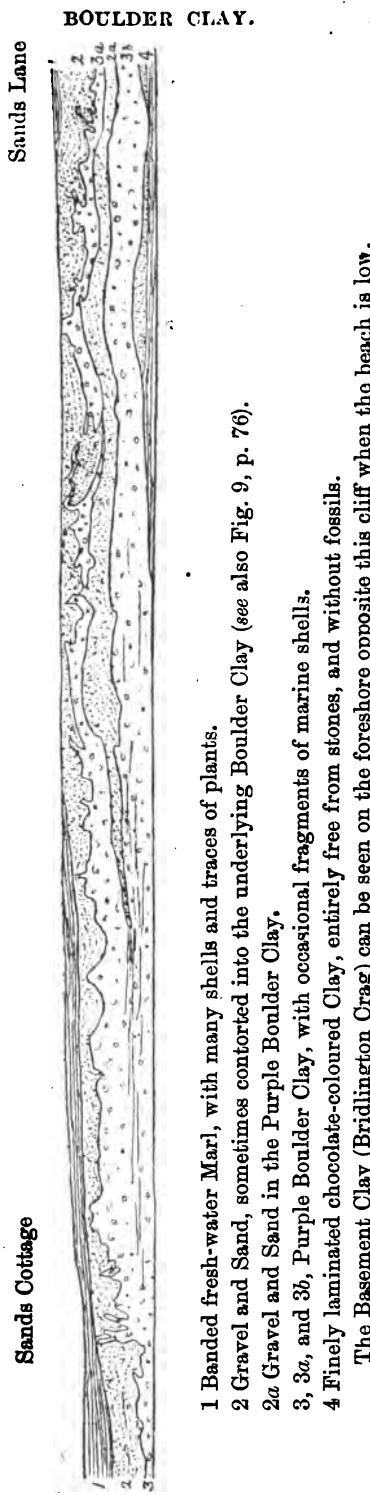
The coarse Chalk Gravel cuts off one end of the Chalk-wash. A little lower down the stream there is fine laminated Clay and Chalk-wash below the chalky Boulder Clay. In the cliff opposite Danes Dike Farm, the section has again varied:—

Sand and Gravel.

Boulder Clay.

Sand and Clay, Warp.

FIG. 3.—Cliff north of Bridlington Quay from end of Wooden Sea Defences 100 yards north of Curr Lane to Sands Lane,
(G. W. Lampugh. *From Proc. Geol. Soc. Yorkshire, n.s., vol. vii. pl. xix.*)
Scale 60 feet to an incl.



- 1 Banded fresh-water Marl, with many shells and traces of plants.
- 2 Gravel and Sand, sometimes contorted into the underlying Boulder Clay (see also Fig. 9, p. 76).
- 2a Gravel and Sand in the Purple Boulder Clay.
- 3, 3c, and 3b, Purple Boulder Clay, with occasional fragments of marine shells.
- 4 Finely laminated chocolate-coloured Clay, entirely free from stones, and without fossils.

The Basement Clay (Bridlington Orag) can be seen on the foreshore opposite this cliff when the beach is low.

Sand.
 Boulder Clay.
 Chalky Gravel.
 Chalk.

The general section of the cliffs, a short distance to the south-west, near Sewerby Hall; Mr. Dakyns gives as:—

Clean red Clay, alluvial.
 Gravel, the Sewerby Gravel.
 Boulder Clay, part of the Purple Boulder Clay.
 Sand, probably the same bed as that which divides the Purple Boulder Clay at Bridlington.
 Boulder Clay, the lower part of the Purple Boulder Clay.
 Chalky Gravel, not continuous, but very general.
 Chalk.

From this point the cliff steadily falls towards Bridlington Quay, and when the old buried Chalk cliff is passed, the beds are more continuous.

At Sands Lane the Boulder Clay above the Basement Clay is divided into two by a thin bed of sand and gravel. This Gravel, according to Mr. Lamplugh, can be traced northward for about a mile, increasing in thickness locally to 12 feet. Beyond the beginning of the Chalk, though the division in the Boulder Clay seems to be continuous, the gravels are intermittent. Between Sands Lane and a point 900 yards south of Bridlington Harbour, Mr. Lamplugh has published detailed sections of the cliff drawn to a natural scale;* and as great part of these sections were only visible for a short time before the sea-walls were rebuilt, his account will be followed, as was done in the case of the Bridlington Crag. South of Sands Lane the bed of gravel thins out within 300 yards, and the two divisions of the Boulder Clay come together. From this point to the spot where the Basement Clay first rises into the cliff, there is a post-glacial freshwater deposit, which cuts into and is mixed with the Boulder Clay in a way that quite prevents any line of division being traced. The clearer section near the Alexandra Hotel shows numerous contorted streaks and masses of sand and clay, which, unlike those in the Basement Clay, do not contain shells, but there are no definite beds of sand. These contortions give the Purple Boulder Clay at this spot much the appearance of the Contorted Drift of Norfolk.

The cliff opposite Bridlington Quay being obscured by the sea-wall and buildings, Mr. Lamplugh has attempted to connect the beds in the north and south cliffs by means of the sections recently exposed in the Bridlington drainage works. These sections, like those seen in the cliff, show two divisions of Purple Boulder Clay overlying the Basement Clay; but nowhere in the neighbourhood of Bridlington is there anything to show whether the two divisions are the Upper and Lower Purple Clay, or whether the so-called Hesse Clay is also represented.

* "Glacial Sections near Bridlington."—*Proc. Geol. Soc. Yorkshire*, n.s., vol. vii. p. 383; vol. viii. pp. 27 & 240.

Immediately south of the Harbour the cliffs are again visible, and for 900 yards from the South Pier we have Mr. Lamplugh's detailed sections. The Boulder Clay answers closely to his description of that in the North Cliff, being "a dark brownish-purple clay, containing a great variety of boulders, and a few shell fragments. The chief point of interest in this section lies in the existence of a well-stratified portion, which occurs along one horizon, and thus forms a band running thread-like throughout the section. This stratified band varies in thickness from a few inches to three feet. It does not differ much from the rest of the clay, except in being bedded, but is rather more earthy (which causes it to weather faster), and also contains a sprinkling of small chalk pebbles, and these are rare in the clay below it, and not plentiful above. It contains scratched blocks like the rest of the Boulder Clay, but flat pebbles are nearly always laid horizontally. The bedding is sometimes very distinct, and almost fine enough to be called lamination; at others it is almost or quite lost, though the state of the cliff has something to do with this, as it is after the washing of a heavy sea that the bedding is best brought out. There are often reddish, whitish, or greenish streaks at its base, which seem to be the remains of crushed masses of soft rocks."

"Its junction with the Boulder Clay below is sharply defined, but upwards it is somewhat vague it rests on, and follows the inequalities of, an extremely uneven surface, rising and sinking in the cliff continually, varying from about 20 feet above the beach to beach-line, and evidently lapping round and over lumpy and projecting bosses of the lower part of the clay,—passing over them sometimes at a high angle;—so that the line traced by this band in the cliff, if called a 'horizon,' is decidedly hilly in aspect." At several points in this section, "the band passes into, or admits, seams of fine clean sand, which appear to have been sheltered under the lee of a boss of the clay-bed, as they are usually sharply cut into, and cut off, by the overlying clay. I have not yet been able to ascertain whether the direction of the leaside is *always* the same, but in two cases the sand rested on the western slope of a knoll."*

The above description of the stratified band is quoted in full, for it will apply not only to the neighbourhood of Bridlington, but to the whole of the Holderness cliffs; and a band, probably of the same age, re-appears south of the Humber, at Cleethorpes.

South of Wilsthorpe the land falls, and the low cliff, where not occupied by alluvial deposits, shows only the Purple Clay with the parting just described, and occasional small contortions. At Skipea the cliff rises again, and south of that place there seem to be indications of the addition of another division of the Purple Clay, or else of the Hessle Clay. A section at Skirlington cliffs, noted by Mr. Dakyns, shows:—

* Lamplugh, *op. cit.*, vol. viii. p. 33.

	FEET.
Boulder Clay	15
Sand (dries out soon)	5
Purple Boulder Clay	5
Gravel and Warp (changes to chalky gravel, 2 feet thick, a little to the south, and to a red band)	3 or 4
Purple Boulder Clay	15

The intermittent bed of chalky sand and gravel in Purple Boulder Clay is probably the same as the red band further north.

The three Boulder Clays, and generally the intervening stratified bands, seem very persistent for several miles, and a few detailed sections will be sufficient to show the character of the deposits. One, half a mile south of the last-mentioned, and close to Moor Hill Beacon, shows:—

	FEET.
Purple Boulder Clay, red and Hessle-like at the top	-
Sand and Warp	1
Purple Boulder Clay, with few stones	8
Clean clay (red band?)	1
Purple Boulder Clay	4

Another opposite Atwick is very similar:—

	FEET.
Sand (alluvial)	7 or 8
Gravel	5 or 3
Boulder Clay	3 or 5
Gravel	3
Boulder Clay	5
Red band	2
Chalk rubble	2
Boulder Clay	—

Near this spot the very chalky base of the Purple Clay is seen at the foot of the cliff. It is probably the bed called by Mr. S. V. Wood, jun., in this neighbourhood, the Basement Clay,* though it is evidently not the same as the shelly Boulder Clays of Bridlington and Dinxton.

Between Atwick and Hornsea, at one or two spots, no line of division could be traced in a clean section of Boulder Clay nearly forty feet high; but close to the edge of the Hornsea Valley one at least of the divisions reappears. The section is:—

	FEET.
Soil	24
Chalky Boulder Clay	8
Clayey Gravel	2
Dark Purple Boulder Clay, with Chalk	23

On the south side of the Valley, where the cliff is over 50 feet high, there is only one line of division, and that is obscure; but slight variations in the character of the Boulder Clay seem to divide it into three:—

	FEET.
Purple chalky Boulder Clay	13
Loamy sand (a contorted lenticular mass?)	2
Dark blue-purple Boulder Clay	20
Red-purple Boulder Clay, with a little Chalk, and shell fragments	12+

* *Geol. Mag.*, dec. II. vol. v. p. 13.

At the brick-yard a short distance further south the uppermost Boulder Clay is nearly black, and perhaps belongs to the middle division of the three, and not to the Hesse Clay.

In Rowlston cliff we again find three definite divisions:—

	FEET.
Purple Boulder Clay, with blue streaks	9
Loamy sand	2
Black Boulder Clay, with chalk	30
Bedded sand, gravel and loam	2
Black very chalky Boulder Clay, with shell fragments	15+

Not far away a boulder of Shap Granite, two feet long, was dug out of the Boulder Clay at the foot of the cliff.

A short distance south, at a spot where the cliff is 70 feet high, there are no lines of division visible. Opposite Mappleton two divisions are seen, which appear to be the Hesse, and Upper Purple Clay, the Lower Purple being below the beach line.

At Easthorpe Hill the "red band" is again seen in the cliff, rising about ten feet above the beach; and opposite Great Colden all the divisions are recognizable:—

	FEET.
Gravel (Glacial ?)	8
Purple Boulder Clay	20
Bedded loam	1
Black Boulder Clay	20
Bed band	1
Lower Purple Boulder Clay	4

Between Colden and Hilston the sections vary so little that it will be unnecessary to give details. The bedded loam of the last section occasionally changes into a thin bed of gravel, and both it and the red band may disappear altogether for short distances; but the Boulder Clay seems nearly always to fall naturally into three divisions. At Hilston an unusually persistent bed of gravel is found between the Hesse and Upper Purple Clays. In the cliff it only extends about 300 yards, but inland it seems perfectly continuous past Hilston church to the Roos Road; and two apparently detached masses of it are found between Hilston and Owstwick. The measured thickness in the cliff is only 13 feet, but inland it appears greater.

The cliffs at Waxham, Withernsea, and Hollym show similar slight variations. The red band is generally found a few feet above the beach line, and is rarely missing when clear exposures can be examined. In this neighbourhood it seldom passes into sand. The higher line of division is here and there marked by the occurrence of lenticular masses of gravel, never exceeding 6 feet in thickness; but usually the cliff from top to bottom is a mass of Boulder Clay, with only subordinate lines in it. One section at Hollym, near Nevill's Farm, may be taken as typical of this district:—

	FEET.
Boulder Clay, with few stones	6
Gravel	3
Boulder Clay, with Chalk	12
Loam, obscurely bedded (red band)	3
Stony Purple Boulder Clay	3+

At Down Gate the red band has risen as high as the middle of the cliff, and immediately north of Holmpton the very chalky base of the Lower Purple Clay reappears on the foreshore. About 300 yards further south the Basement Clay also rises above the sea level, and south of this point all the beds seem to rise with the rise of the surface of the ground towards Dimlington Height. At Dimlington High Land itself, which reaches an elevation of 135 feet, the Basement Clay occupies about 20 feet of the lower part of the cliff, but there is so much talus that it is not easy to trace its junction with the overlying Purple Clays. Where the higher part of the cliff is clear, no continuous lines of division are traceable, and the Boulder Clays seem unusually disturbed and contorted.

Due north of Out Newton, and not far from Dimlington, a boulder of Shap Granite, measuring $3 \times 2\frac{1}{2} \times 2$ feet, was found on the foreshore at extreme low water. Being only exposed at very low spring tides I was unable to ascertain whether it was embedded in the Boulder Clay, or had slipped down from the cliff. This is the furthest point to the south-east to which Shap Granite has yet been traced.

The way the different Boulder Clays successively rise above the sea level, to fall again when the High Land is passed, and the way they are contorted and disturbed, strongly suggests that the present is not their normal position, but that Dimlington Height is a mound composed of Drift Deposits of different ages, forced up during the latest glaciation.

Towards Easington the cliff sinks, and opposite that place only the base of the Lower Purple Clay and the Basement Clay are found. Near Kilnsea the foreshore shows a very chalky Boulder Clay, which is apparently the base of the Lower Purple Clay, the true Basement Clay having sunk beneath the sea-level a short distance south of Kilnsea Beacon. This chalky division is traceable as far as Great Pit Marsh, where the Boulder Clays finally disappear, and recent marine deposits take their place.

A distance of nearly eight miles, occupied by the Humber, separates Kilnsea cliff from the next section; but at Cleethorpes, on the Lincolnshire side, Boulder Clay reappears. The short section at Cleethorpes, half a mile in length, is the only cliff between the Humber and Hunstanton in Norfolk. The Boulder Clay is purple and stony, especially in the lower part. In general character and included boulders it seems to correspond closely with the higher divisions on the Yorkshire coast.

The section usually shows a line of division, along which lenticular masses of sand often appear; but this line is difficult to trace, unless the face of the cliff has been washed perfectly clean by storms. On one occasion, when the tides had cleared away the beach to an exceptional extent, another line of division was seen, apparently corresponding to the "red line" of the Holderness coast; but the section was not low enough to show what came beneath. There is apparently a considerable thickness of Boulder Clay beneath the sea-level, for a boring between

tide marks at Cleethorpes Pier is described as passing through 60 feet of "marl clay" before reaching the Chalk. The cliff is nearly 40 feet high, so the total thickness of Boulder Clay must here reach about 100 feet. A few shell fragments were observed in the lower part of the cliff, but they were rare and very small.

Inland Sections of the Boulder Clay.

The differences between the upper divisions of the Boulder Clay are so slight, and there is so much difficulty and uncertainty in tracing the beds, even with a nearly continuous cliff section, that it is evidently quite hopeless to attempt to correlate isolated inland sections by their lithological character. The differences that are found so often disappear when the beds are traced laterally, and are so largely due to chemical changes and weathering, that the cliff section probably might be locally inverted without any one finding it out. Of course this only refers to the upper three divisions; the Basement Clay is sufficiently distinct, though, as already observed, we have no right to expect its shelly character to continue for an indefinite distance.

Although the greater part of Holderness is covered with Boulder Clay, there are very few good sections in the interior; and the following notes include all which can be clearly seen, and show anything but a few feet of Boulder Clay of the common type. For the mapping of the country there was abundance of evidence in the deep ditches, except where it is low and marshy.

Commencing at the north, the sections shown in the valleys or gills cutting into the Chalk near Flamborough have already been described. The next were those exposed during the progress of the drainage works recently completed at Bridlington Quay; but as these are so near the sea, correspond so closely with those seen in the cliff, and are now entirely hidden, it will be sufficient to refer to Mr. Lamplugh's paper, where full details are given.*

Further west and south-west thin Boulder Clay is occasionally seen overlying the Chalk, but, as is generally the case on the Wolds, it appears to be much weathered. On the low grounds instructive examples of this weathering are also found, and the sections being deeper, the whole process can be more readily traced. Mr. Dakyns points out that the extent of the change is sometimes curiously governed by the nature of the overlying bed, and notes a good instance of this, seen at a brick-pit near Nafferton. The Boulder Clay was in part covered by sand, and the clay below the sand was blue; but where there was little or no sand over it, the Boulder Clay was weathered red. The line between the two colours was, in a proper light, very distinct, and ran down nearly

* G. W. Lamplugh: "Glacial Sections near Bridlington." Part III.—The Drainage Sections.—*Proc. Geol. Soc. Yorkshire*, n.s., vol. viii. p. 240.

vertically from the feather edge of the sand across a homogeneous mass of clay, which was of precisely the same character on either side of the colour line. Besides the red topping to the purple Boulder Clay due to weathering, there were also bands or beds of Red Clay in the midst of the Purple Clay, that is, beds of red Boulder Clay, which are both over- and under- laid by Boulder Clay of the ordinary purple type.

In the valley of the Hull the ground is so low that pits cannot be kept free from water, so the only sections are occasional exposures in the ditches. West of the Hull the drainage sections at Driffield showed well the intricate way in which Boulder Clays and Gravels are mixed and interbedded on the edge of the Wolds.

These sections throw no light on the general question of the age of the Boulder Clay, though apparently two divisions are represented. They were described by Mr. Mortimer in 1881,* but of course cannot now be seen. In the same paper Mr. Mortimer alludes also to the crushed and glaciated surface of the Chalk seen near Driffield. This is a common feature in the Wolds, especially near the edge, and is also found throughout Lincolnshire, West Norfolk, and Suffolk. In places where the Boulder Clay has either not lodged, or been entirely denuded, it is often the only evidence of glaciation.

In several pits near Hutton there is reddish Boulder Clay overlying the Chalk. The north edge of Beledmond Chalk-pit shows—

	FEET.
Red Boulder Clay	4
Weathered (Glaciated?) Chalk	15
Chalk without flints	—

The west edge of the same pit shows six or seven feet of Boulder Clay, and the south-east corner—

	FEET.
Red Boulder Clay	2
Light-coloured chalky Boulder Clay	4 or 5
Chalk	—

The Hutton Chalk Pit is equally variable, the northern margin showing—

	FEET.
Clay with a few stones	1
Gravelly sand	3 or 4
Chalk	—

while at the south-east corner there is—

	FEET.
Reddish Boulder Clay	8
Chalk without flints	—

At Cawkeld Chalk-pit, about a mile south-west of Cranswick, the irregularity of the Chalk surface under the Drift is very marked. The red Boulder Clay is generally free from Chalk, but

* J. R. Mortimer : "On the Sections of the Drift obtained by the New Drainage Works at Driffield."—*Proc. Geol. Soc. Yorkshire*, n.s., vol. vii. p. 373.

where it lies on a deeply eroded surface of Chalk it contains abundance of Chalk fragments. The Drift layers dip both east and west. A very similar section is seen in the Chalk Pit immediately east of Holme on the Wolds.

On the east side of the River Hull wells at Catfoss, Hornsea, and Mapleton show numerous alternations of Boulder Clay and Gravel; but as all of them are only borings, except the upper 73 feet of the Hornsea Water-works well, it is impossible to give any exact description of the beds. There is also no means of distinguishing between true beds of sand and mere sand galls, and it is very probable that some of the divisions in the Hornsea wells may be only lenticular masses in the Basement Clay, corresponding with those seen in the cliff at Bridlington and Dimlington. Full details of these well sections will be found in the Appendix.

The sections near Beverley call for no remark, except that one on the Hessle road, close to Bramble Hill, shows well the effect of weathering. Overlying Chalk without flints is 10 or 15 feet of Purple Boulder Clay with scratched stones, weathering reddish with ashy joints.

The greater part of the southern half of Holderness being very low shows few good exposures, except in the cliff, and at Hessle and Kelsey Hill. Boulder Clay, weathering like that just described, is mentioned as occurring at the bottom of the excavations for the Albert Docks, Hull, separated from a lower bed of Purple Boulder Clay by a seam of sand.* Numerous well-borings penetrate to the Chalk, but the details are generally of little real value. Some good exposures were laid bare in the cuttings for the Hull and Barnsley Railway, where it entered the Wolds, though nothing was seen but weathered reddish Boulder Clay resting on Chalk, or only separated from it by a foot or two of rubble or chalky gravel. In places the Chalk was glaciated and broken up to a depth of several feet.

The only other sections of interest north of the Humber are those at Hessle and Kelsey Hill. Having been taken by Mr. S. V. Wood as the type of his "Hessle Clay," these will be described fully; but it may be at once observed that neither of the sections can be accepted as showing the original character of the Boulder Clay. In each case it has undergone great alteration and weathering.

The Hessle sections show Boulder Clay overlying mammiferous gravel, but overlapping it and resting directly on the Chalk where the cliff becomes higher. At present the exposures are bad, but Prof. Phillips has published an account of them, as seen in 1826, in which he gives several sections, and describes the Boulder Clay as a thick bed of brown and blue clay, with chalk, flints, granites, gneiss, syenite, limestone, porphyry, hornstone and coal. He also found what seemed an elephant's tusk.† Similar clay can still be seen both here and at several spots in the neighbour-

* J. C. Hawkshaw: "The Construction of the Albert Dock," &c.—*Proc. Inst. C. E.*, vol. xli. p. 492.

† Phillips: "Notice of the Hessle Drift as it appeared in sections above Forty Years since."—*Quart. Journ. Geol. Soc.*, vol. xxiv. p. 250.

hood. Mr. Cameron observes that in the low cliff of North Ferriby there is a purple chalky Boulder Clay, the upper portion of which weathers red.

The Boulder Clay overlying the gravel at Kelsey Hill ballast pit, near Keyingham Station, on the Hull and Withernsea line, is so much weathered, though nearly 13 feet thick, that for a long time I felt uncertain whether it was anything but rainwash. The common occurrence of flints in it seems, however, to show that originally the deposit was a chalky Boulder Clay; but all, or nearly all, calcareous matter having been dissolved out, it is now simply a stony loam or brick-earth. South of the Farm the Boulder Clay sinks almost to the marsh level, and in the railway cutting it has become purple and chalky. A short distance north there is no Boulder Clay on gravel hills over 50 feet in height, but no definite system can be traced in these irregularities. Another Boulder Clay, in this neighbourhood only known from borings, underlies the Gravel, and seems to rise to the surface around Keyingham. These sections will be again referred to in the Chapter on the Marine Gravels.

Under the Humber there is evidently a considerable thickness of Boulder Clay, though none of the borings yet made have shown the full depth of the old, probably pre-glacial, Humber Valley. Mr. Kelsey, the engineer to the North-eastern Railway Company, has kindly communicated to me a series of borings across the Humber. (See Appendix I. p. 151.) They prove that Boulder Clay, interstratified with sand and gravel, reaches a depth of at least 83 feet below the present level of high-water; and, judging from the dip, there will be a still greater thickness in the old channel, but borings Nos. 5 and 6 were not continued sufficiently far to settle the depth of the Chalk. This question of the depth of the old channel will be more fully discussed in Chap. X.

On the south shore of the Humber, a well made some years ago at Killingholme Coast Guard Station penetrated through Warp and Boulder Clay to a depth of 107 feet, without reaching the Chalk. Here again the old channel seems to have been found.

A section seen in the low cliff of South Ferriby is the only exposure of Boulder Clay on the south shore of the Humber. It corresponds closely with that seen at North Ferriby, and exhibits Boulder Clay separated from the Chalk by thin ripple-marked flaggy sandstone. From this point eastward, Boulder Clay forms a belt separating the Chalk Wold from the Humber flat, clearly showing that the ancient Humber Valley was not only deeper but wider than the present one, and was subsequently partially filled with Drift, through which the present river is excavating its channel.

At Barton-on-Humber, drainage works and wells showed good sections of purple chalky Boulder Clay of the ordinary character; and similar though less chalky clay irregularly overlies the Chalk in the large pits west of the town. The lower part of the little Dale which runs west-south-west into the Wolds is also filled with Boulder Clay; a well about a quarter of a mile from Mount Close

has been sunk through 15 feet of clay before reaching the Chalk. This old channel filled with Drift seems to be continued under the town, towards the Humber, though there is now no trace of it at the surface. From the descriptions of the well-sinkers and builders, the old Dale is very well defined under the Drift, and must have steep sides like the Wold Dales of the present day. At the junction of King Street and High Street there is, according to Mr. Westaby,—

	FEET.
Clay and Chalk (Boulder Clay)	30
Gravel	33
Chalk	—

Probably this is about the centre of the channel, for other wells in the town show the Chalk much nearer the surface.

South of Barton, Boulder Clay stones are scattered over the Wolds to a height of about 150 feet, but there is nothing to show positively whether the Boulder Clay has been denuded, or whether no more Drift ever lodged there. The Chalk is often glaciated to a depth of several feet, and foreign stones have been forced into it.

The ditches around Barrow and Goxhill show numerous exposures of a purple Boulder Clay, but the only good section is in a sand-pit about a mile north of Barrow church. Here a very chalky Boulder Clay overlies the sand, appearing to follow the slope of the hill; the greatest thickness seen is only three feet, though wells in the neighbourhood show that in places it becomes much thicker. The Boulder Clay at the surface in the low lands seems usually to overlie the fossiliferous gravel; but at the edge of the Wolds, near Thornton and Ulceby stations, Boulder Clay rests directly on the Chalk, perhaps rising from beneath the gravels. Nearer the Humber the intervening gravels are often missing, the two Boulder Clays coming together, as they apparently do on the coast. Many of the borings show nothing but clay above the Chalk, though others show two beds of Boulder Clay separated by gravel.

Boulder Clay of the same character is found all through the low lands between Halton and Grimsby, but there being only ditch sections, with the exception of a small pit at Great Coates, it is unnecessary to give further details. Along the edge of the Wolds, however, the relations of the beds can be well observed, and Boulder Clay can be seen both over- and under-lying the fossiliferous gravel. The surface Boulder Clay of the low lands overlying the gravel thins out about a mile from the Wold edge; and as the gravels rise, patches of an older Boulder Clay are found to be preserved between them and the Chalk. The outliers at Ulceby may be one of these, though in this instance the absence of the gravels prevents the true age being definitely determined. However, in the large valley of Croxton, through which the railway passes, the evidence is perfectly clear; for not only is Boulder Clay seen in ditches at the bottom of the Dale, but on digging in the centre of two pits in stratified fossiliferous gravel very characteristic chalky purple Boulder Clay was found. It is also

interesting to find that this Boulder Clay is, in its lithological character, quite indistinguishable from the newer chalky and purple Boulder Clay which overlies the Gravel a short distance further east. The sections being near the bottom of the valley, show conclusively that the Dale existed before the deposition of this lower Boulder Clay, and that its deepest erosion is unconnected with the Gravel Period.

Near Brocklesby, Limber, and Irby there are apparently other outliers of the same Boulder Clay, though the want of open sections prevents their relation to the Gravel being definitely proved. South of Laceby the Gravels suddenly thin out, the two Boulder Clays come together, and there is nothing to show whether it is the upper or lower one which rests directly on the Chalk.

Returning to Grimsby, some of the most interesting sections were exposed during the main drainage works, which were going on during my stay there. These showed two Boulder Clays, purple, chalky, and exactly alike, separated sometimes by a mere line of division, sometimes by gravelly sand in which fragments of the inter-glacial shells were found. Though the sections were examined almost daily, not the slightest difference could be detected between the two Boulder Clays, either in their matrix, or in the included boulders. There is a seaward dip in the beds, so that the line of junction between the two clays on the north is a good deal below the level of high water; but to the south, as the upper Boulder Clay rose above high-water level, its character gradually changed; it lost much of its calcareous matter, and joints with a blue and green mottling on their faces appeared in it. This weathered Boulder Clay is still visible in a sand-pit close to the Roman Catholic Church, where it wraps round a mound of the fossiliferous inter-glacial sand. Being fully exposed to the weather, the Boulder Clay has changed into a stony brick-earth.

Brick-yards near Grimsby and Cleethorpes show deep sections of the Boulder Clay, sometimes with a line of division in it. One of these pits, near Cleethorpes, has been dug to a depth of nearly 20 feet below high-water, but shows only a chalky purple Boulder Clay, like that of the cliff, but showing no divisions. At another, about half a mile south-east of Grimsby station, a large collection was made of stones from the Boulder Clay. Among them was a block of Rhomb-porphyry, a very marked and characteristic rock from the neighbourhood of Christiania, and also numerous boulders of the Halleflinte and Porphyrite. Many of the other rocks are also probably Scandinavian, though they have not at present been definitely traced. They included red Flint (Danish), Gneiss, Mica Schist, Garnetiferous Hornblende Schist, hard Sandstone or Grit, Carboniferous Limestone, Diabase, and several varieties of Quartz or Felspar Porphyry.

Great caution is necessary in this district in the collection of Boulder Clay stones; for enormous quantities of Scandinavian and Russian rocks are brought annually in ballast from the Baltic ports, are used for road metal, and find their way on to the fields in manure. They are usually, however, Basalts and garnetiferous

Gneiss of a quite different character from any yet found in the Boulder Clay.

Between the Wold and the salt marshes near Tetney and Fulstow the belt of Boulder Clay becomes narrower; the Gravels have died out; and, there being no sections, it is impossible to say whether only one or all of the Boulder Clays are represented. Well sections seem to show that the Drift is banked against a very steep slope, if not an actual cliff of Chalk.

Summary.

The details given above, and in the Appendix, show clearly to what a large extent the original features of the country have been obliterated or rendered less marked by the partial filling up of the valleys with Boulder Clay. In their pre-glacial state the Wold valleys were much deeper, and more like ravines, though now the Boulder Clay has partially filled their lower extremities, and glaciation has widened them and rounded off their margins. Of destruction by the ice there is very little evidence, and probably it was not extensive. The principal sign is the curious shallowness of the soil, and the nearness of bare Chalk to the surface. This apparently points to the removal of a large mass of flints and weathered Chalk; for usually the Chalk is very flinty, and Pliocene weathering would produce a mass of loose flints like that often found in the South of England and France. At the present day there is nothing of the sort preserved in the Wolds, and bare Chalk is constantly reached by deep ploughing.

Another point brought out is that some at least, even of the minor Dales, existed not only before the deposition of the Marine Gravels, but before the deposition of the immediately underlying Boulder Clay. The large extent to which the Marine Gravels have been preserved beneath the Boulder Clay also shows that this latest ice-sheet deposited, but did not here erode much. And, reasoning by analogy, we may consider that the older ice-sheet also eroded but little; the main features as we now see them being the result of ordinary sub-aërial and marine denudation, and dating back to a still older period. Of the exact period during which this erosion occurred we can say little, for the changes which took place during the early part of the Glacial Epoch are still little known, and we have reason to believe that they may have been considerable.

The general direction of the flow of the ice-sheets seems to have been from the east and north-east, for it appears that a considerable proportion of the boulders must have come from Scandinavia. The question, however, is much complicated by the common occurrence of rocks derived from portions of the English coast lying to the north of Holderness, and also of Shap Granite from Cumberland. From the state of preservation of many of the boulders it would appear that the transport has been

by no means a simple process. Chalk and limestone boulders bored by annelids or *Pholas*, and subsequently striated, are very abundant in the Boulder Clay, and appear to show that the ice-sheet has ploughed up an old sea-bottom, over which abundance of far-transported rocks had been scattered by shore-ice. The fragments of marine shells were probably derived from a similar source. Of local glaciers there is no trace in the Wolds.

One point often incidentally alluded to in the foregoing detailed description of the Boulder Clays is so important, and so constantly overlooked, that special attention must be drawn to it; this is the continual chemical change going on in the Boulder Clay, even at considerable depths beneath the surface.

It may be taken as a rule of general application that if a Boulder Clay contains flints and no Chalk it is a weathered Boulder Clay, and will be reddish in colour and generally have green-faced joints. Fortunately there is abundance of evidence of this entire solution of the calcareous matter in the Holderness Boulder Clays. Numerous continuous sections show the passage of red stony loams into bluish chalky Boulder Clay.

But this alteration is not confined to Holderness; it is the general rule in the Norfolk cliffs, and wherever in the Eastern Counties the Boulder Clay is slightly pervious or thin. Where the Boulder Clay is impervious and clayey it is only superficially affected. The correlation of red colour, greenish joints, and absence of chalk, is therefore of no value as marking a definite horizon, for all these characters are only the result of the percolation of water with carbonic acid in solution. The same agency that dissolves out the Chalk alters the oxidation of the iron in the Boulder Clay.

Thus, though we find reddish stony loams of similar character over large tracts both in Yorkshire, Lincolnshire, and Norfolk, there is good evidence that the resemblance is only accidental. On going to West Norfolk after finishing Holderness I found this weathering still more marked. At Hunstanton there is a low cliff (the first south of Cleethorpes) showing stony Boulder Clay without Chalk, quite of the "Hessle Clay" type. But by tracing it on the foreshore till it passed beneath the sea-level it was found to change both laterally and vertically into a lead-coloured very chalky Boulder Clay of the ordinary Norfolk type. A curious result of the dissolving out of so large a quantity of calcareous matter is that the residual mass must subside and pack more closely. In the subsidence the component parts generally become to some extent rearranged and flattened out, so as to give a deceptive appearance of bedding.

CHAPTER IV.

STRATIFIED GLACIAL BEDS.

The stratified deposits associated with the Drift appear to fall naturally under two heads: the true Inter-glacial beds, and the Gravels and Laminated Clays which probably may have been formed contemporaneously with the Boulder Clay. The latter, as being the most intimately connected with the Boulder Clay, will be described first; but with them must be included various isolated deposits, which, from the absence of fossils, cannot definitely be referred to the marine Inter-glacial Gravels. Some of these may ultimately have to be placed in that division, but the majority are probably of fresh-water origin.

The clayey Gravels which overlie the Chalk at Flamborough have already been alluded to; they contain only derivative fossils of the same species as are found in the Basement Clay, and probably represent merely an upland modification of the tough unstratified Till of Holderness. Such apparent passages of Boulder Clay into clayey Gravels are not uncommon in hill districts, and can be still better seen in North Yorkshire, especially near Whitby and in Eskdale. Some of the chalky Gravels interstratified with the Boulder Clay, filling Danes Dike and other valleys near Flamborough, probably may have been deposited in sub-glacial watercourses, for they vary continually, and have yielded no fossils. Their general character is shown in Fig 2, p. 29, reduced from a sketch by Mr. Dakyns. Similar chalky Gravels very often separate the Purple Boulder Clay from the Chalk, between Flamborough and Bridlington; and judging from borings, this bed may pass under the Basement Clay also.

Southward the succession of the Drifts becomes more definite, the different Boulder Clays being often separated from each other by beds of sand or clay. Commencing with the lowest seen in the cliff section:—south of the spot where Chalk first rises above the sea, lying on the Basement Clay there is a bed of brown laminated clay, becoming more persistent south of Bridlington. This, according to Mr. Lamplugh, in the cliff never rises above the level of the highest tides, and is best seen on the foreshore. He observes that “the clay is chocolate-coloured, and very fine and tough. It is beautifully laminated, and in places ripple-marked, and contains no pebbles nor other foreign admixture, save in its lowest layers. It rests on an eroded surface of the ‘Basement Clay,’ which has been worn into deep hollows. Upwards, it is cut off abruptly by the Purple Clay wherever it rises much above beach level.” . . .

At one spot he mentions that the laminated clay “passes upward into sand with clay partings, which is in one place seven feet thick. This is only seen for a short distance; the base of the Purple Clay above is forced down irregularly over it, and shows slickensides.” . . . Immediately south of the South Pier at Bridlington

Quay "the laminated clay completely fills the deep and wide hollow in the Basement Clay on the beach, so that it has here a thickness of about 16 feet; elsewhere it rarely exceeds four or five feet." The foundations of the sea-wall were laid in this hollow, with the result that it slipped along the greater part of its length, and the work is now left in an unfinished state.

"There is a thin seam of chalky gravel between the laminated clay and the underlying Boulder Clay in the bottom of the hollow; and this, whenever tapped, yields copious supplies of very pure water, which wells out at high tide, but ceases to flow at ebb. . . . The well known ebbing and flowing spring in the harbour is probably supplied from the same source."* Mr. Lamplugh's account is here quoted, for his long residence on the coast has given him unequalled opportunities of thoroughly examining portions of the bed only rarely exposed.

Near Dimlington this bed reappears, though very commonly the Lower Purple Clay rests immediately on the Basement Clay. In this neighbourhood, however, the laminated clay of Bridlington is largely replaced by sand and gravel in irregular lenticular masses. At one spot, directly under Dimlington Height, there is no less than 20 feet of sand and bedded loam between the Basement Clay and the chalky base of the Lower Purple Clay, but this thickness is quite exceptional.

Though the horizon has been carefully searched, both by the Geological Survey and by Mr. Lamplugh, no trace of contemporaneous fossils has yet been found. That this is not due to the dissolution of all calcareous matter, is proved by the occasional occurrence of a fragment of a shell washed out of the underlying Basement Clay. Even if shells do not occur, marine clays, when unaltered, almost invariably contain foraminifera and other microscopic fossils. None can be found; and it is not only on the Holderness coast that laminated clays of this character are perfectly barren, but wherever similar clays occur they seem to have been equally devoid of life. In Eskdale, and on the Norfolk coast, laminated ripple-marked clays are of common occurrence associated with the Boulder Clay, and in neither case could anything but derivative fossils be found.

At the present day no sea is thus devoid of life, and clays obtained from moderate depths invariably contain organic remains. Ordinary fresh-water clays, if unaltered, also contain fossils, though commonly in smaller number; and it is apparently only in ice-dammed lakes and similar situations that animals and plants cannot thrive.

From this it would appear that the laminated clays may not belong to a true inter-glacial period, but may only point to a partial retreat of the ice, as has already been suggested in the case of the similar beds near Cromer.† Another explanation, which

* "Glacial sections near Bridlington." Part II.—*Proc. Geol. Soc. Yorkshire*, n.s., vol. viii. p. 27.

† *Memoirs of the Geological Survey*,—Geology of the Country around Cromer, p. 19.

necessitates less change, and perhaps accounts even more satisfactorily for the utter absence of life, is that many of the stratified beds intercalated in the Boulder Clay were deposited in water under the ice. Water must often have accumulated to a large extent in hollows under the ice-sheet, where the ground was nearly level; thus portion of the sheet would float, though perhaps only a few inches from the bottom, and the material falling through the water would be stratified.

This sub-glacial origin of the stratified beds would account for the absence of life; but there is the difficulty, that if the bottom of the ice contained any boulders, they ought to be found in the stratified clay; while, as a matter of fact, the entire absence of stones is one of the most marked characteristics of these beds. Perhaps the most probable explanation is that the laminated clays represent glacier mud, deposited in shallow lakes within a short distance of the ice-foot.

The next horizon on which stratified beds are found is that lying between the Upper and Lower Purple Clays. This is commonly represented by the "red band," consisting of from 1 to 3 feet of reconstructed or stratified Boulder Clay, probably also rather weathered. The gravels that occur on this horizon on the coast are usually very thin, impersistent, and either from their coarseness unlikely to yield many fossils, or else the decayed state of the Chalk and derivative shells shows that any fossils may have been entirely obliterated. At one spot only were shells found. This was at Easington, where the bed has reached the exceptional thickness of 8 feet; but the shells were so decayed that they could not be extracted, nor the species determined. As the fossiliferous gravels of Kelsey Hill may come in on this horizon, the section will be again referred to when the better inland exposures have been described.

A third horizon of stratified beds is seen on the coast lying between the Upper Purple Clay and the so-called "Hessle Clay." This consists of sub-angular gravel, apparently derived from the Boulder Clay, or at any rate from the same source as the Boulder Clay. It rests on an irregular surface of the underlying clay, though there is no evidence of any great erosion, and no trace of deep channels cut in the Boulder Clay.

This Gravel is more persistent, thicker, and can oftener be examined than either of the lower horizons; but as far as yet searched,—and it has been carefully searched in many places,—it has proved quite unfossiliferous. It is to this bed that Messrs. Wood and Rome give the name "Hessle Gravel," correlating it with the mammaliferous gravel lying directly on the Chalk in the pits and cliff of Hessle, and also with the marine gravel of Kelsey Hill. A detailed survey of the country has scarcely supported this view, for it seems more probable that the unfossiliferous gravels of the coast are ordinary glacial gravels, unconnected with any true Interglacial period. The equivalents in the coast-section of the fossiliferous gravels so well represented inland will be discussed in the next Chapter.

Inland, with the exception of the Marine Gravels, very little gravel and sand is seen at the surface, though nearly all well-borings pass through one or two beds before reaching the Chalk. The gravels capping the cliff at Bridlington, if glacial, are so mixed with post-glacial beds that they will be described in a future Chapter. Near Hornsea the hill on which the water-works stands is capped by 12 feet of sand, which appears to overlie the "Hessle Clay;" but this sand does not extend so far as the cliff, and there is no trace of it elsewhere in the neighbourhood.

Most of the other patches mapped are very indefinite in their boundaries, and apparently only thin. One near Aldbrough seems to be the outcrop of a large and unusually thick lenticular mass of the gravel beneath the Hessle Clay, and is probably nearly continuous with the bed exposed in the cliff opposite. There is another similar inland extension of this bed at Hilston. The other outliers north of the Humber call for no further notice; few of them show any section, and the stratigraphical relations of none of them are clear, though all would appear to lie above the Marine Gravel.

South of the Humber there is a marked absence of gravel, except on the horizon of the shelly marine beds. Patches, however, occur at Scartho, Barnoldby, Waltham, and Holton, but none of them are now worked; and as gravel is fetched long distances from Laceby, they would appear to be of little economic value. Borings prove the occasional occurrence of another bed of gravel, lying on the Chalk, as in other parts of Holderness, but this bed is not seen at the surface.

Clean laminated clay has been worked at the Brick-kiln between Barnoldby and Waltham. At the time of my visit this section was very obscure, though the laminated clay appeared to be a bed in the Boulder Clay. There is nothing to show on what horizon it occurs.

CHAPTER V.

INTER-GLACIAL BEDS.

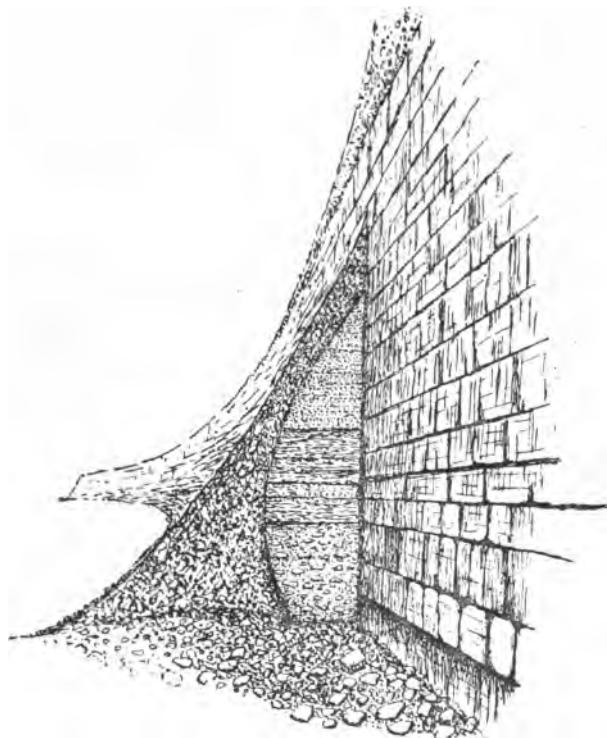
MAMMALIFEROUS GRAVELS OF BRIDLINGTON AND HESSLE.

The Inter-glacial Beds of Holderness belong to two types,—Marine Gravel, and Gravel containing only mammalian bones. These can scarcely be contemporaneous, for while the former shows a submergence of 100 feet, the latter, as far as the evidence of one of the sections goes, must have been deposited when the sea stood at about its present level. The two types may belong merely to different stages of the same Inter-glacial Period; but, on the other hand, one may be considerably older than the other, and separated from it by Boulder Clay. The Hessle Gravels Prof. Phillips considered to be Pre-glacial, and much older than the Marine Beds.

But, without following him so far,—and the evidence of the fossils is against this view,—as a matter of convenience the Mammaliferous Gravels resting directly on the Chalk will be described first.

During the spring of 1884 Mr. Mortimer informed me that at last the sea had cleared away the talus, and exposed a good section of the buried cliff near Bridlington. In the early part of May I had the advantage of his guidance to the exact spot where, not far from this cliff, he had obtained mammalian bones. Next day, by employing a labourer for a few hours, the very important section here figured was laid bare.

FIG. 4.—*Buried Cliff near Bridlington, and Fossiliferous Beds banked against it.*



The old cliff proved to be perfectly vertical for over 30 feet and cuts the present coast line at an obtuse angle. Banked against it is a series of deposits unlike any thing else in Holderness. Rising about 5 feet above the level of the present beach is shingle, composed almost entirely of Chalk, often bored by *Pholas*, mixed with a few of the local grey flints.

Though Boulder Clay lies on the cliff almost vertically above this beach, yet, with the exception of a single fragment of silicious ironstone of doubtful origin, no foreign boulders could be found in it. This at once distinguishes the old beach from the recent shingle, for at the present day there is a very large number of Boulder Clay stones on the shore.

Above this beach there is a roughly stratified mixture of marly sand, chalky wash, and fallen angular blocks of Chalk,—in fact just such a talus as forms at the foot of a Chalk cliff out of reach of the sea. In the middle of this, fragments of an antler of *Cervus megaceros* were found, and the matrix of Mr. Mortimer's specimens (*Bos* or *Bison*) seems to show that they also come from the same bed. This talus is about 5 feet thick, and above it is fine dust-like sand, with rounded equal-sized grains—apparently Blown Sand.

The Blown Sand was banked against the cliff to a height of 22 feet above the present beach, but the amount of recent talus in the way prevented the section being cut back till undisturbed Boulder Clay could be actually seen to overlap it. Before long, however, the sea will probably clear away the slipped Boulder Clay, and expose a still better section. The rounded hummocky face of the old cliff is very suggestive of the continued action of wind-drifted sand; it is markedly different from the angular or quadrate forms taken by the hard Yorkshire Chalk under the ordinary action of weathering, and is also quite unlike a glaciated surface.

The stratigraphical relations of this old beach to the Glacial Beds cannot satisfactorily be made out. If Mr. Lamplugh is correct in tracing the Lower Purple Clay over the top of the cliff, it is evident that the beach must be older than that division. But the Basement Clay apparently does not rise in the same way; and though it can be traced to within a few hundred yards of the cliff, there is no direct evidence to show whether it is older or newer than the Inter-glacial Beds. If newer, it might be expected to extend as far as the cliff,—and it may prove to do so when the talus is cleared away. If older, it is difficult to understand the absence of Boulder Clay stones in the beach, when a very stony Boulder Clay occurs within such a short distance.

It is also curious that near Bridlington Quay, that is to say, some distance from the old shore, the top of the Basement Clay rises well above the sea. This could scarcely have been the case while the beach was forming at the same level, for it would necessitate the almost impossible feature of an undestroyed bank of soft clay rising a short distance off shore just to high-water mark,—that is to say, to the exact height at which marine denudation is most active. Such a bank would not last a single season, much less while the cliff of hard Chalk was being cut back to a perfectly vertical face.

Another fact which appears to tell in favour of the extension of the old shore deposit beneath the Basement Clay, is the occurrence of a similar mass of Chalk Gravel in borings at Bridlington Harbour, resting on the Chalk, and clearly beneath that clay. This Gravel lies at about the depth one would expect to find the sea-bottom half a mile from a rocky shore.

Leaving Bridlington, the deposits banked against the old cliff are entirely unknown until we reach the Humber. Here, at Hessle, is the well-known Gravel originally described by Prof. Phillips, and considered by him to be Pre-glacial. The most

striking feature of this neighbourhood is the steep slope of the Chalk towards the Humber, forming what is commonly called Hessle Cliff, though it is by no means vertical. On this lies irregularly the mammaliferous Gravel, covered and overlapped by Boulder Clay.

The first section is an overgrown pit by the side of the line, just west of Hessle Station, which shows at its south-west corner,—

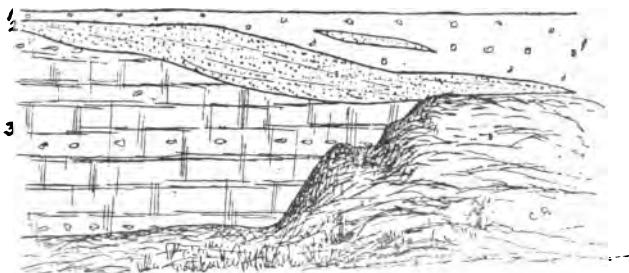
	FEET.
Purple Boulder Clay, weathering with greenish joints.	
Many small fragments of Chalk, but few large boulders	10
Bedded sand with Chalk, looking very like an old "run of the hill"	?
Chalk	—

About 100 yards north, and close to the line, the section is,—

	FEET.
Boulder Clay as before	8
Bedded sand	½
Chalk rubble	4
Chalk	—

Here the surface of the Chalk has risen considerably. The cuttings further west are now much overgrown, but the sections are similar to the above, the Chalk having a steep south slope.

FIG. 5.—Chalk-pit at Hessle.



1 Boulder Clay. 2 Sand and gravel. 3 Chalk.

The diagram, Fig. 5, represents the north side of the large pit still further west. It shows Boulder Clay overlapping the Gravel, and resting directly on the Chalk; and also that there is not only a north and south slope of the Chalk, but also an east and west irregularity, probably an old channel connected with the Humber. In this or the adjoining pit bones of *Elephas primigenius*, *Rhinoceros*, *Equis caballus*, *Cervus*, and *Bos*? have been found; but no marine fossils are yet known, though the deposit is a long way below the level of the old shelly gravels with which it is often correlated.

From these details it will be seen that we have really nothing by which to fix the age of the Hessle Gravel. It lies on the Chalk, and is covered by a Boulder Clay; whether another under-

lying Boulder Clay has been denuded there is no positive evidence. What is the age of the overlying Boulder Clay we cannot say; it may correspond with any of the divisions on the coast, or with a division unrepresented there. For convenience the Hessle and Bridlington sections have been taken together, but at present it is unsafe to correlate them, though the general structure of Holderness renders it extremely probable that they may be contemporaneous. Prof. Phillips' reference of the Hessle Gravel to a Pre-glacial period may turn out, with fuller evidence, to be well founded, though, as far as they are yet known, the fossils do not appear to support this view.

South of the Humber the only deposit which can with any likelihood be correlated with the Hessle Gravel is a thin bed of ripple-marked sand or sandstone, in South Ferriby Cliff, resting on Chalk and overlaid by Boulder Clay. At present no fossils are known from this locality. Further south there are no sections whatever at the foot of the Cliff, and the feature dies away under the alluvial flats of South Lincolnshire, without a single important valley cutting through it between the Humber and Wash.

Marine Gravels.

As far back as 1821 William Smith noted on his map the occurrence in the interior of Holderness of what he considered were Crag shells. The beds containing them, now known to be of much later date than the Crag, have since been more fully examined and described, and prove to lie between two masses of Boulder Clay.

Prof. Phillips, who examined the sections at Brandsburton and Kelsey Hill in the year 1826, gave no account of the stratigraphical relations of the Gravel, though he seems to infer that it is closely connected with the Boulder Clay.* The first full description of the bed and its stratigraphical position was published in 1861, when Prof. Prestwich pointed out that the Gravel was underlaid by Boulder Clay, and probably, though not certainly, overlaid also by Boulder Clay.† Subsequently, in 1868, Messrs. Wood and Rome showed that better sections at Kelsey Hill had distinctly proved that Boulder Clay overlies the Gravel. They also state that they "strongly incline to think that the Kelsey Hill Gravel is only an unusually thick and fossiliferous development of the Hessle Gravel."‡ Since that date nothing has been added to our knowledge of the bed.

As this fossiliferous horizon is a very important one in the Glacial Deposits of Holderness, and seems to be the only one holding out much prospect of allowing correlation with other parts

* *Geology of Yorkshire*, 1st edition 1829, and 2nd edition 1835.

† "On the Occurrence of the Cyrena fluminalis, together with Marine Shells of Recent Species, in beds of Sand and Gravel over beds of Boulder Clay near Hull."—*Quart. Journ. Geol. Soc.*, vol. xvii. p. 446.

‡ Wood and Rome: "On the Glacial and Post-glacial Structure of Lincolnshire and South-east Yorkshire."—*Quart. Journ. Geol. Soc.*, vol. xxiv. p. 146.

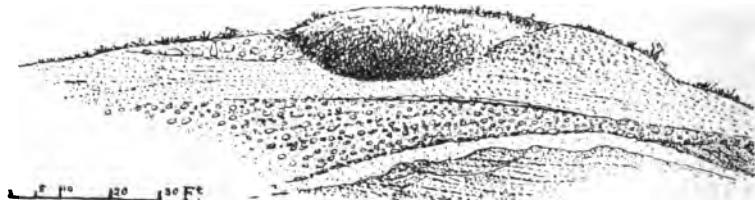
of England, the sections will be described fully, all general remarks being left till afterwards.

The most northerly sections of the true Marine Gravels of Holderness are found at Kilham, lying in a Wold valley which opens into the old bay at its north-east bend. They appear to reach a height of nearly 100 feet above the sea, and contain fragments of *Tellina balthica*, *Cardium edule*, *Cyprina islandica*, and *Mya*.

Continuing southward along the margin of the old bay, or, what is practically nearly the same thing, following the 100-foot contour line, the next exposure is at Nafferton. Here, immediately below the 100-foot line, there is Marine Gravel, with fragments of *Cardium edule*, *Mya*, sp., *Mytilus edulis*, and *Tellina balthica*, overlying thin Boulder Clay, and containing abundance of derived Boulder Clay stones. This rests on the shelving surface of the Chalk. South of Nafferton no Marine Gravels have yet been observed west of the river Hull, and the shore deposits of the old bay would appear to have been entirely denuded from the slope of the Wolds.

North-east of the Hull, commencing near Little Kelk, the Gravel forms a series of ridges 20 or 30 feet high, resting on and partly overlaid by purple Boulder Clay. The best exposures are seen between Brunton Hill Wood and Barf Hill, a pit at the latter place exhibiting the section sketched by Mr. Dakyns (Fig. 6). This exposure is important, as showing that the Marine

FIG. 6.—Barf Hill.—Inter-glacial Gravels overlaid by Boulder Clay.



Gravel is beneath a bed of Boulder Clay. Boulder Clay is seen in the upper part of the pit, and the structure and shape of the ground appear to show that another Boulder Clay also passes beneath the ridge. In this pit, and in another about half a mile further north, the following species of Mollusca were found, all of them being forms already known from Kelsey Hill:—

<i>Ostrea edulis</i>	<i>Pholas crispata</i> .
<i>Astarte borealis</i> .	<i>Tellina balthica</i> .
<i>Cardium edule</i> .	<i>Venus ? gallina ?</i>
<i>Cyprina islandica</i> .	<i>Dentalium entalis ?</i>
<i>Mactra ovalis</i> .	<i>Buccinum undatum</i> .
<i>Mya truncata ?</i>	<i>Purpura lapillus</i> .
<i>Ostrea edulis</i> .	<i>Balanus</i> , sp.

These Gravels continue in the same line for some distance to the south, but the ground being lower there are no open sections. At Brigham, and Church End, North Frodingham, two more

mounds of gravel, about the same height as those just described, are seen. These have yielded a few fragments of marine shells.

The next sections are three miles further south, near Brandsburton. Here, at Brandsburton Barf, are the pits already noticed by Phillips. The Gravel forms long mounds about 20 feet high, known in different parts as Barf Hill, Coneygarth Hill, Fosse Hill, &c. Pits have been opened at various places, and fossils obtained at Burshill, Barf Hill, Coneygarth Hill, Goose Hill (close to Starcarr Bridge), Gildholm Hill, Fosse Hill, and Gravel Field (near Catwick); in fact, wherever search has been made, the beds have proved fossiliferous, though the shells as a rule are very fragmentary. The pit near Burshill has yielded *Astarte borealis*, *Cardium edule*, *Cyprina islandica*, *Mya*, sp., *Purpura lapillus*, *Tellina balthica*, and *Balanus*, sp. The gravel at Brandsburton village rests on Boulder Clay, and seems also to pass under Boulder Clay towards the north and east.

Similar gravel extends continuously as far east as Seaton, keeping the same fossiliferous character, and in places rising, like the mounds already described, 50 feet above the sea. The eastern termination is rather obscure, owing to the Marine Gravel being overlaid by the old Terrace Gravel surrounding Hornsea Mere. Apparently the marine bed sinks rapidly near Seaton, and is overlapped by Boulder Clay.

About four miles further south, Lambwath Beck cuts into gravel, probably the same bed, and North Skirlaugh is built upon it. But though gravel is exposed for about a mile and a half, there is no section, and it is impossible to speak with certainty as to its age. The large outlier at Rise seems distinctly on a newer horizon, for its base is about 60 feet above the sea, while the top of the older sand, only a short distance away, scarcely reaches 50 feet, and its base is below the stream level. At Rise there is also a well passing through two beds of sand separated by Boulder Clay, the lower sand corresponding in position with that of Lambwath Beck.

The low lands of the Hull Valley show no sections of Marine Beds, though some of the patches of sand coloured on the map may belong to this horizon. East of the Hull there is an exposure, south of Sproatley, in which are two pits in coarse chalky gravel, both of which yield fossils; but the only shells obtained were fragments of *Cardium edule*, *Cyprina islandica*, and *Tellina balthica*. The relation of this gravel to the Boulder Clay is obscure, though, from the character of its boundary, it may well be a lenticular mass. As is the case with all the patches of Marine Gravel in the low lands of Holderness, the greatest height to which it rises is 50 feet.

The next exposures border on the flats a few miles east of Hull. Going eastward the first to be reached are a number of sand-hills lying between Hedon Haven and the Humber. Into one of these the stream has cut, forming a low cliff facing the Humber for nearly a mile, but never rising over 30 feet above high water. This is the well-known section a High Paull mentioned by

Phillips and Prof. Prestwich; but since they wrote it has been sloped and built over for the Battery, and cannot now be examined.

The fullest account of the appearance of the cliff before it was hidden is that given by Prof. Prestwich,* who describes the section as showing sand with but little gravel, containing the same shells as Kelsey Hill, but in fewer numbers and more broken. This sand reposed on an irregular surface of grey clay; but, the clay containing no boulders or fossils, he could not feel certain about its being Boulder Clay. Subsequently, in digging below the base of Paull Cliff, Mr. Smith soon found the clay to become stony, and the specimens he sent to Prof. Prestwich had the ordinary aspect of Boulder Clay. The section measured by Prof. Prestwich was:—

		FEET.
Cliff section	Soil and silty gravel	8
	Sand and gravel with shells	12
	Sandy dark-coloured clay without stones	6
Section obtained by digging at the foot of the cliff.	Clay with stones (Boulder Clay)	—

Further east Mr. Cameron notes a pit-section near Newton Garth showing,—

	FEET.
Small gravel, with marine shells, much coal, and various foreign pebbles	7

and also another pit on the south side of Boreas Hill in similar beds. Numerous other hills south of Hedon rise through the Alluvium to a height of about 25 feet, but none of them show sections. About Ryhill the Gravel forms a considerable spread not exceeding 25 feet above mean tide. A pit bordering on the Marsh showed,—

	FEET.
Sand and gravel with numerous shells	9

On the north side of the railway the land becomes much higher, at Kelsey House exceeding 50 feet, and Gravel forms an extensive spread bordering on the marsh, and overlapped irregularly by Boulder Clay. Many years ago a ballast pit was opened in this hill, and worked so extensively that it is now a quarter of a mile long. This is the typical section of Kelsey Hill, so fully described by Prof. Prestwich and Messrs. Wood and Rome; but not having been worked for some years, great part of the pit is now overgrown. However, at one spot a clear face of about 12 feet of much weathered Boulder Clay with small stones can be seen overlying the Gravel. The Gravel rises about 35 feet above the marsh level; and to test its thickness Prof. Prestwich and Mr. Smith had a boring made from the bottom of the pit, expecting "to find the base of the gravel at a depth of 10 or 12 feet; whereas, after penetrating with difficulty to a depth of 36

* *Op. cit.*, pp. 452, 453.

feet, always in the gravel, but the lower bed more argillaceous, the work had to be abandoned. These borings at Kelsey Hill gave,—

							FEET.
Sand and gravel with shells	-	-	-	-	-	-	4
Larger gravel	-	-	-	-	-	-	16
Smaller gravel	-	-	-	-	-	-	8
Larger gravel in grey loam (Boulder Clay?)	-	-	-	-	-	-	8
							36

From this it would appear that the Gravel must be upwards of 60 feet thick at Kelsey Hill, probably as much as 80 feet.

The Gravel is false-bedded and shingly, with beds of sand; and Prof. Prestwich noticed in it pebbles of limestone with scratches more or less obliterated, proving that in part it was derived from an underlying Boulder Clay, though in this place the lower Boulder Clay must be much below the sea-level. Fossils are common, and one of the most noticeable peculiarities of this locality is the extraordinary abundance of the fresh-water *Corbicula fluminalis* mixed with the marine species. Even now this shell may be picked up in hundreds scattered over the floor of the pit and in the ballast of the line.

Quite recently another closely adjoining pit has been opened, to provide ballast for the concrete at the Alexandra Docks, and for the new railway. This pit is being worked so fast that the sections vary from day to day, and before long the excavation will be as large as the old one. As seen in May 1884 it showed at the north end a perfectly clear face of boldly current-bedded shingle and sand of about 40 feet, without any trace of Boulder Clay. On the west side, also about 40 feet high, and close to Kelsey House, a purple chalky Boulder Clay overlies the Gravel, resting most irregularly on it (see Fig. 8 p. 75). This disturbance is probably, in part at least, subsequent to the deposition of the Boulder Clay; for a fresh-water alluvial deposit in one place fills a basin in the Gravel lined with Boulder Clay, and is apparently contorted with it.* This Boulder Clay sweeps down towards the marsh both south and east of Kelsey Hill farm, its base descending from 50 feet above the sea to about 20 feet in a quarter of a mile.

In both pits the Gravel has been worked till water is reached, but the same shingly current-bedded character is found throughout. The stones are principally flint and chalk, with many foreign rocks derived from the Boulder Clay, but no large boulders. Derivative Jurassic *Ammonites* and *Gryphaea incurva* also occur. Among the stones are many blocks and pebbles of Chalk bored by *Pholas*, showing that in places the sea must have cut into bare Chalk and not Boulder Clay.

The fossils are like those of the abandoned pit, but there are naturally slight differences between different parts of the same

* See also p. 76.

hill. It is interesting to note that Dr. Jeffreys' list from the old pit contains several species not found by the Survey; and the Survey list, principally from the new pit, contains several not found by Dr. Jeffreys. The slight differences in these adjoining pits are quite as great as are found on opposite sides of the Humber, or even between the Gravels of one extremity of Holderness and the other.

From both pits mammalian remains have been obtained; but, unfortunately, many of those found in the earlier workings were not preserved, and the new pit yields fewer than the old. The bones in the collections of Mr. Freeman (presented to the Geological Survey), Mr. Mortimer, Messrs Lucas and Aird, and the Hull Museum, belong to *Elephas primigenius*, *Rhinoceros leptorhinus*, *Bison priscus* (very abundant), *Cervus tarandus*, and *Trichechus rosmarus*, but no small mammals are yet known. Only one or two indeterminable fragments and some fish vertebrae were found in the course of the Survey. This, however, is no test of their abundance, as the whole of the collection from the new pit was made during a few hours, and the sand was not sifted for teeth of voles or fish. A full list of the fossils from Kelsey Hill will be found at p. 70.

About half a mile from Kelsey Hill, in the north-east continuation of the same Gravel, there are two small pits; one, not far from Gospel Hill, showing a patch of Boulder Clay overlying the Gravel. These yielded several species of mollusca corresponding with those of Kelsey Hill. Still further north-east, at Rea Hill, near Ridgemont, the Gravel sinks, and is apparently overlapped by Boulder Clay.

Southward, Keyingham is built on the Gravel, which here rises to a height of 65 feet, though overlapped within a short distance by Boulder Clay. South-west of Keyingham the Gravel reappears, skirting the marsh, and only reaching an elevation of 25 feet. A pit due south of St. Phillip's Cross has yielded *Buccinum undatum*, *Ostrea edulis*, *Cardium edule*, *Mactra*, sp., *Tellina balthica*, and *Corbicula fluminalis*, the last shell being much scarcer than at Kelsey Hill, only a mile distant.

Crossing the Humber at Hull, Marine Gravels reappear on the south side near Barrow and Goxhill, forming a belt which stretches for ten miles along the foot of the Wolds. The first section reached is a small pit half a mile north-north-east of Barrow Monastery. Here there is,—

	FEET.
Soil	2
Boulder Clay, very chalky, apparently following the slope of the hill	0 to 3
False-bedded chalky sand, with a few small stones; no shells observed	7+

A pit a few yards higher up the hill shows only sand, without Boulder Clay. The absence of shells in the above section is unusual, but is probably due to the constant shifting of the sand.

In other pits seams of fine unfossiliferous chalky sand sometimes alternate with shelly gravel.

From this point to Littleworth the Gravel is overlapped or cut out by Boulder Clay; the upper Boulder Clay sometimes resting directly on the lower one. That the Gravel is not so disconnected as would appear from the map, is, however, shown by numerous wells on the Barrow and Goxhill road. For nearly a mile these pierce the upper Boulder Clay, and derive their supply of water from the Gravel, which yet makes little show at the surface.

South and east of Littleworth the Gravel is exposed along the course of the Beck, and overgrown pits show that it must be of some thickness. The first open section is a small pit close to the rail, a quarter of a mile north of Thornton Station. Here false-bedded gravelly sand is dug to a depth of about eight feet, and broken shells can be found throughout. The species obtained were *Cardium edule*, *Cyprina islandica*, *Mactra subtruncata*? *Pecten islandicus*? *Tellina balthica*, and *Balanus*, sp. Another pit close to the Station shows 12 feet of fine sand, with a patch of small gravel at the top, but it is much overgrown. A pit close to the stream west of Long Looks shows sand and false-bedded chalky gravel of Boulder Clay stones, with rolled pebbles of loam and marl. All the Gravels in this neighbourhood show the influence of strong currents, and appear to have been constantly shifting banks.

In a pit near Ulceby Station there is about nine feet of gravelly sand and loam, the lower part passing into false-bedded chalky and carbonaceous sand. North-west of the station a deep and long ditch exposes chalky Boulder Clay, rising from beneath Gravel, and resting immediately on the Chalk. On the east side of the stream the Gravel appears to pass under an upper Boulder Clay.

South of Ulceby the 100-foot line (there are, however, no levelled contour lines yet in Lincolnshire) sweeps into an old submerged valley; and in this sheltered arm of the sea, as we should expect, there is a marked improvement in the state of preservation of the fossils, and at last we obtain evidence of comparatively still water. A section in Brocklesby Park, just outside the shelter, shows only gravelly sand, with much-broken shells, including *Cardium edule*, *Cyprina islandica*, *Mactra subtruncata*, *Tellina balthica*, and *Dentalium entalis*. But a small pit, a mile further west, near the rail, and not far from Croxton, shows a decided change, whole shells being abundant, and delicate species preserved. With the assistance of Mr. A. W. Raven I dug through the sand, and reached Boulder Clay in two adjoining pits, the section in the upper one being as given below:—

	FEET.
Soil	1
Well-worn sandy Gravel with shells	3
Sand with fewer shells	7
Chalky purple Boulder Clay	1
	12

It is interesting to find Boulder Clay beneath the Marine Gravels, not only in the open districts, but even in a deep valley like that of Croxton.

A full list of the shells obtained at Croxton is given at page 70. The fauna is essentially the same as that of the Kelsey Hill and Laceby, with the addition of a single specimen of a very thin *Tellina*, apparently *T. tenuis*, and a portion of *Cytherea chione*. Both are species unknown elsewhere from this horizon. The *Corbicula fluminalis*, of which three specimens were found, is at present unknown from any other locality in North Lincolnshire, though abundant at Kelsey Hill. The abundance of *Scrobicularia piperata* and *Rissoa (Hydrobia) ulvae* shows the proximity of areas of tidal mud, though the bed in which they are now preserved is clean sand.

At Kirmington, a mile south of the last section, a still more marked change takes place. On a high-lying gently inclined surface of the Chalk and Boulder Clay an outlier of the shore deposits of the old sea has been preserved. These consist of *Scrobicularia* warp, very like that now forming between tide-marks in the Humber, marsh peat, and well-worn flint shingle. The elevation above the sea is apparently about 80 feet, but there are no levelled heights in the neighbourhood to guide one. Pits on the north side of the village show the best sections, that at the brick-yard giving,—

	FEET.
Well-worn beach shingle, principally flint, but a few large white quartzites	10
Laminated warp with <i>Scrobicularia piperata</i> , <i>Rissoa ulvae</i> , <i>Tellina balthica</i> , <i>Cardium edule</i> , <i>Mactra subtruncata</i> , <i>Mytilus edulis</i> , and abundance of <i>Foraminifera</i>	10
Peat, consisting almost entirely of reeds	$0\frac{1}{2}$
Warp with <i>Rissoa ulvae</i>	0 to 1
Sand	6
Chalky gravel, not pierced (from the information of the brick-makers)	<hr/> 27

The shingle is systematically worked off the Warp, and is also extensively dug in a pit on the other side of the road. As is necessarily the case where coarse gravel has been rolled about and deposited on soft clay, the shingle rests on an eroded surface of the Warp. The Warp is similar to that of the Humber, and contains, like it, in certain seams, abundance of *Scrobicularia*, *Rissoa*, and *Tellina balthica*. Of the other species we have only the young. *Tellina balthica* is always the thin-shelled estuarine form. This thoroughly agrees with Mr. H. B. Brady's remark about the *Foraminifera* collected at the same time, that "the species and the appearance of the specimens alike indicate a starved shallow water fauna."

The Peat Bed is a most unsatisfactory deposit to examine. It is composed entirely of reeds; at least nothing else determinable could be found in it; no seeds, no wood, no moss, and no elytra

of beetles, such as peat ordinarily contains. It does not appear to be a drifted deposit, as the underlying bed is full of small roots; neither does it necessarily show any great change of level, for fresh-water lagoons full of reeds often form behind shingle beaches, and their surface may be several feet below high-water of the sea outside, though it cannot be below the level of mean tide. Reeds may also grow out of water a foot or two in depth.

Beneath the Peat there is another impersistent bed of Warp full of *Rissoa ulvae*, showing alternations of estuarine and fresh-water conditions. The sand beneath, owing to water being reached, could only be examined to a depth of 5 feet; but the brick-makers state that it is 6 feet thick, and rests on gravel, the lower part occasionally containing shells. There is, however, nothing to show whether these are fresh-water or marine, or whether the statement is correct. The part exposed was ferruginous, and contained no trace of either Chalk or fossils; it had evidently lost its calcareous matter by solution. Probably the Chalky Gravel is but thin, and rests directly on the Chalk.

The brick-makers stated, and Mr. S. V. Wood, jun., alludes to the same fact, that at one part of the pit the brick-earth fills a basin-shaped hollow, in which, several years ago, large bones (apparently antlers of deer) were found, but sold for grinding up into bone dust.

On the other side of the little valley that runs through the middle of the village of Kirmington, there is also clean laminated clay, which in the cellars at Mr. Frankish's house is 10 feet thick, and rests on sand from which water is obtained.

Around Kirmington Vale there is also sand and sandy loam, which may be either a modification of the Warp, or of the accompanying Sand. There is no clear section.

Still higher up the Dale there is an outlier of Gravel, consisting of rolled Chalk, slightly worn flint, and a few foreign pebbles. This is probably a valley deposit, of the same age as the Inter-glacial Beds, and it is worth careful searching for mammalian remains. Unfortunately I could never find the men at work to inquire whether any have been found.

Leaving the Croxton and Kirmington fiord, we pass the open sea deposits of Brocklesby, and soon reach another inlet. This is much less interesting, for it appears to have been more open and exposed to the run of the sea. It has two entrances separated by an island of Chalk. At the mouth of the southern one, near Keelby Grange, there is an overgrown pit showing 15 feet of small Gravel and Sand, with abundance of shell fragments. A list of the species obtained, 17 in number, will be found at p. 70; they all occur at Kelsey Hill and Laceby.

Near Limber Nursery Boulder Clay appears from beneath the Gravel, but everywhere else in the neighbourhood the Marine Beds overlap the Boulder Clay, and rest directly on the Chalk. Great Limber is partly on Gravel and partly on Chalk, the Gravel lying in a valley, and with its limit generally well-defined

by a sharp rise of Chalk. The town Gravel Pit yielded a few shell-fragments.

South-east of the village there is a brick-yard showing the following section :—

								FEET.
Soil and loam	-	-	-	-	-	-	-	6
Blue Warp	-	-	-	-	-	-	-	15
Pan	-	-	-	-	-	-	-	1
Sandy loam	-	-	-	-	-	-	-	1
Buff sand	-	-	-	-	-	-	-	5
Sand (bored)	-	-	-	-	-	-	-	9 or 10
								37 or 38

Similar laminated Warp, 4 yards thick, is said also to occur at the cross roads near Limber Schools, though it is apparently hidden by Gravel. The abrupt rise of the Chalk at Limber brick-yard is very curious; for one of the cottages belonging to the pit is on Chalk, while not 80 yards away, on the same level, there is at least 37 feet of Sand and Warp.

The Warp was searched for shells and microscopic fossils, but nothing whatever could be found. Probably it is the same Warp as that at Kirmington, and the absence of Foraminifera is due to dissolution of the calcareous matter. On close examination it is seen to be full of rase, concentric iron stains, and incipient ferruginous concretions. It seems to be a general rule in all formations, that where this structure is found, any calcareous fossils will be dissolved away; the two changes, solution of the carbonate of lime and oxidisation of the carbonate of iron, generally going together.

South of Limber a long strip of the Gravel has been mapped as running up Fox Dale, but it is very doubtful whether this is entirely correct. For half a mile south of the Irby road there is certainly worn gravel, but the higher part of it may be merely blown sand and rain-wash lodged in the bottom of the valley.

About half a mile north-east of Great Limber Cover there is a curious section showing,—

							FEET.
Soil and sandy gravel	-	-	-	-	-	-	0 to 4½
Boulder Clay, with Chalk and foreign stones, mostly small	-	-	-	-	-	-	5 to 0
Pockets of pebble gravel	-	-	-	-	-	-	—

The upper gravel is apparently part of the outlier mapped, but what the nests of pebble gravel belong to is not clear. Near the southern end of the same outlier, an old pit and some rabbit burrows show gravel containing shell fragments.

Half a mile south-south-east of Keelby a large Chalk-pit shows, near the middle of the north-east side,—

							FEET.
Stony soil	-	-	-	-	-	-	1
Loamy bedded Sand, with a few scattered stones	-	-	-	-	-	-	5
Rolled Gravel of Boulder Clay stones	-	-	-	-	-	-	5

Chalk with flints, dip to the north-east, very slight - 20+

At one spot in this pit, near the wood, about $2\frac{1}{2}$ feet of Boulder Clay is preserved beneath the Gravel, which is here a well-worn very coarse shingle, principally of Chalk and flint.

In Riby Grove several sand-pits have been opened, but the only section now to be seen (1883) is just west of the house:—

FEET.

Gravelly Sand, with shell fragments and a few perfect shells -	4
--	---

Unfortunately this is a very small and bad exposure, but it is evidently highly fossiliferous, and with a clear section more than the 18 species found ought to be obtained. The list is given in the table.

Irby Dale appears to have been another old fiord, the Gravel running up it in much the same way as at Croxton; but now the Marine Beds are only represented by patches separated by denudation. One of these caps an isolated Chalk hill rising in the middle of the Dale due north of Irby. Another a little higher up clings to the west side, at Irby Dale woods. A pit in this outlier shows,—

FEET.	
Fine false-bedded sand and gravel, with carbonaceous matter, and fragments of <i>Cardium edule</i> , <i>Tellina balthica</i> , <i>Mactra subtruncata</i> , <i>Astarte borealis</i> , and <i>Mya</i> , sp.	4

Still higher up the valley a pit in the outlier above the Folly gives,—

FEET.	
Bubbly and worn Chalk Gravel, with a few foreign pebbles -	20+

This is capped at the lower end by a foot of chalky Boulder Clay; and from the clayey wet nature of the ground to the south, there may be a small outlier of Boulder Clay extending a few chains in that direction. The Gravel would seem to be a high-lying estuarine or fresh-water equivalent of the Marine Beds.

The isolated Chalk hill immediately north of Swallow village, is also capped by similar gravel. In a pit close to the last house there is:—

FEET.	
Gravel of rolled Chalk, with a few Boulder Clay stones -	5
Chalk with flint nodules	10

The higher parts of this large Dale apparently contain no Gravel.

North of Irby Holmes Wood there is an old pit in similar rolled Chalk Gravel, resting partly on Chalk. Its relation to the Boulder Clay is not clear, though it probably passes under it.

Returning to the open country, the only pit between Riby and Laceby is a large one in Laceby Hill. This Hill rises as a conspicuous mound, like those north of the Humber, to a height of about 50 or 60 feet. The section is,—

FEET.	
False-bedded gravelly Sand, with masses of Shingle in the lower part (worked till water is reached) -	40

Abundance of Boulder Clay stones are found, though Boulder Clay cannot here be seen either above or below the Gravel. Boulders of Chalk bored by *Pholas* and annelids are common. Fossils are plentiful and well-preserved, but the only important difference between the list and that from Kelsey Hill is the

entire absence of the fresh-water *Corbicula fluminalis* from Laceby. No fresh-water shells, and no mammalian bones have yet been found there.

South of Laceby the Gravels are abruptly overlapped by Boulder Clay, and for a long distance cannot be found. North-east of Laceby, after disappearing for about a mile they re-appear in the shallow valley of Laceby Beck, and are probably close to the surface, though never rising to any height, all the way from Laceby to the Humber Marshes.

At Great Coates there is an interesting inlier, cut into by the Beck. A pit a short distance from the north-east side shows,—

	FEET.
Chalky Purple Boulder Clay (on the higher ground) -	1 to 5
Gravelly Sand, with shell fragments principally near the top	1.2

This pit was deepened till water was reached, and shows that the base of the Sand must be below the level of the Marsh, which is about the level of ordinary high tides. Mr. Cordeaux and myself obtained here the 17 species of mollusca given in the table. They are very fragmentary, though small light shells are sometimes little injured. Special attention was paid to this pit, as it is one of the few places where Boulder Clay can be clearly seen in section vertically over the shelly Gravels.

The same Sand Bed passes under the Boulder Clay on which Great Coates is built, and supplies the wells. Mr. Cordeaux also informs me that in lowering the cellar at his house this bed was cut into, and yielded such a constant supply of water that a special drain had to be constructed to carry it away. From the amount of water it would appear that sand must extend for some distance under the Boulder Clay; and it is probable that the bed is continuous with that outcropping in Laceby Beck, and bordering on the Marsh between Little Coates and Grimsby.

In Grimsby itself, close to the Roman Catholic Church, a small sand-hill rose above the level of the Marsh, but has lately been almost entirely dug away. It showed sandy Gravel with rare shell fragments, including portion of *Venus gallina*, overlaid by a much-weathered mottled stony Boulder Clay, with little or no Chalk. In the recently completed drainage works, which lie considerably beneath high-water level, the upper Boulder Clay was seen gradually to cut through this Sand towards the Humber, and in places to rest directly on the lower Boulder Clay, with only a reddish line of division. The base of the Sand also sinks in the same direction, though more slowly. At the corner of Wellington Street and Heneage Street the section is,—

	FEET.
Soil and made ground -	2
Peaty clay -	5
Chalky Boulder Clay -	3
Sand with stones and shell fragments (rising to the south) {	2½
<i>Cardium edule</i> , <i>Tellina balthica</i> , <i>Mactra subtruncata</i> ? <i>Mya</i> , sp. {	0½
Chalky Boulder Clay -	0½
	<hr/> 13 <hr/>

The surface of the ground is about the sea level.

Eastward this is the last section of the Marine Gravels, which apparently sink beneath the sea level, or are cut out by the newer Boulder Clay. Southward there are no more exposures in the district under consideration, but, as pointed out to me by Mr. Jukes-Brown, the bed reappears 20 miles away, beyond Louth. A pit three-quarters of a mile south of Claythorpe Station shows,—

FEET.

Shingle and sand, with a large number of Boulder Clay stones, and abundance of fossils - - - - about 8

From this pit, during a single short visit, the 21 species of mollusca in the list were obtained. Probably with fuller search this would prove a very prolific locality, especially as the section is clear and easy to examine.

CHAPTER VI.

INTER-GLACIAL BEDS—*continued.*

PHYSICAL GEOGRAPHY.

In the last Chapter it was shown that Marine Gravels can be traced round the greater part of old bay of Holderness. But they are not strictly limited by the Chalk cliff, for where that cliff is low they overlap it, and extend some distance beyond. During the earlier part of this Inter-glacial period the land was apparently bounded by the now hidden Chalk cliff, though that feature is probably in the main of still older date, and the submergence was only to about its present extent. Subsequently the sea rose, or the land sank, and the 100-foot contour became approximately the shore-line. Of greater submergence there is little evidence. Near Limber shelly Gravels extend to a height of considerably over 100 feet, perhaps nearly 200, though the absence of levelled heights prevents us fixing the limit accurately. Nowhere else in the district has any trace of the Marine Gravels been yet found above 100 feet.*

A gradually increasing submergence seems the most satisfactory way of accounting for the apparently contradictory evidence of the sections at the foot of Bridlington Chalk cliff, and of Kilham and Kirmington. It is clear that beds in such close proximity, showing a sea-level differing by 100 feet, cannot be exactly contemporaneous; yet there is no satisfactory evidence in this district of two successive Inter-glacial Periods. The simplest explanation is, perhaps, that these different deposits merely mark successive stages in one Period.

One fact, which without this explanation is difficult to understand, is the non-occurrence of any marked feature in the Chalk

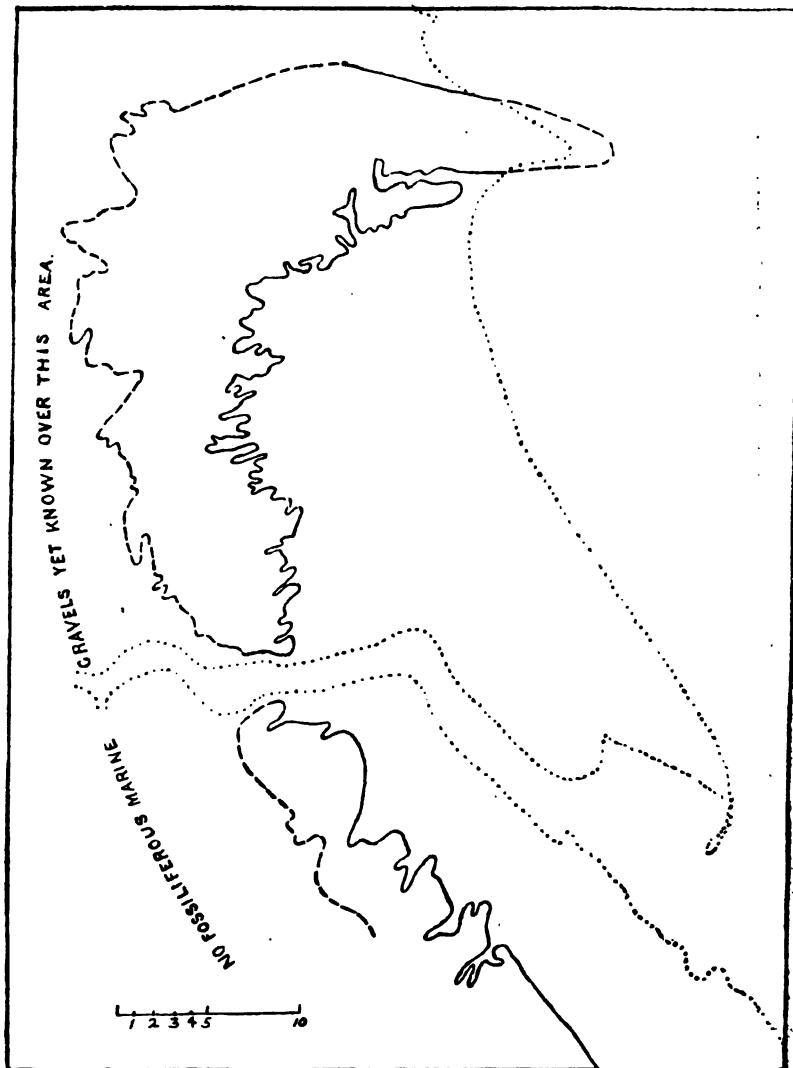
* The shells in the high-lying gravels at Flamborough Head are derived from the Boulder Clay.

immediately above the ordinary limit of the Marine Beds. This was a constant difficulty during the mapping of the country ; for, taking the sea-level to have been unchanged during the whole of the time, it is evident that the Period must have been very short, or we should find a Chalk cliff above the 100-foot line, very similar to the older one. Such a feature does occasionally limit the Marine Beds in North Lincolnshire, but it is so insignificant that, if not especially searched for, it would have passed unnoticed. If the land were slowly sinking, the absence of any limiting feature is readily accounted for. Even the lower cliff is probably only in part due to Inter-glacial erosion, the sea having in places cut back the soft Boulder Clay till it was stopped by the bold Pre-glacial cliff of hard Chalk.

Of this Inter-glacial Period we know but little ; in fact, of its earlier and later stages, nothing at all. The conditions can scarcely have changed abruptly from glaciation to a temperate sea, and back again. There must have been intervening stages when an arctic fauna and flora flourished, though the ice had partly melted back ; but of these we have no direct evidence, and there is now a distinct line of erosion at the base of the gravel, and another above. The missing passage beds seem thus to be only represented by erosion. There is but one part of the Inter-glacial Period which we know at all well ; represented by beds formed when the submergence was about 100 feet. Of this stage the deposits are so well preserved that without much uncertainty we can venture to give a map of the old bay.

In this map one of the most noticeable peculiarities is the way the sea runs up the submerged Wold valleys, turning them into fiords, and here and there depositing in them banks of shelly sand. These valleys cannot have been formed during an earlier stage of the same Period, for in the bottom of several of them, underlying the Gravels, are occasionally preserved patches of an older Boulder Clay. They must, therefore, belong to a still earlier Inter-glacial or Pre-glacial Period of valley erosion ; and this Period, from the extent of the erosion, must have been of considerable length.

Tracing the deposits round the margin of the old bay, one is struck very forcibly by the resemblance of the Gravels to the constantly shifting banks which are so common in the North Sea at the present day. It is only here and there in sheltered fiords that we find anything but current-bedded gravel and sand, and only in the large fiord of Croxton and Kirmington that comparatively still-water deposits are now preserved. There we have tidal warp, corresponding with that now forming in the Humber ; but, with the doubtful exception of the Limber brick-yard, there is only one small outlier of it. Shingle beaches are also represented in the same place, and sandy beaches not far off. Lower down, and formed in a depth of from 1 to 15 fathoms, are shifting banks ; but nowhere can we get sufficiently low to find deeper-water deposits, or still-water clays, like those which contain the " Bridlington Crag " shells.

FIG. 7.—*Sketch Map of Inter-glacial Holderness.*

In this map, on a scale of about 10 miles to the inch, the approximate limit of the old bay is defined by a continuous black line. The broken line is carried on at the same level round the west side of the Wolds; but no trace of old beaches having there been found, it is doubtful whether Inter-glacial Marine Gravels ever extended over the Oolitic plain. Flamborough Head has been drawn projecting 2 miles beyond its present limit, to allow for the denudation which has taken place in Post-glacial or Late-glacial times. The dotted line shows the limit of the present land and its relation to the ancient coast line. The map extends from Speeton Bay and Flamborough Head, in Yorkshire, to Donna Nook, in Lincolnshire.

The Gravels appear to dip seaward with as much regularity as can be expected in deposits of this character. The dip must, however, be measured by the slope of the denuded surface of the underlying Boulder Clay, not by the irregular level of the top of the Gravel, which was either deposited in banks or has been subsequently most unevenly denuded.

Making traverses of the bay at different points, we find the base of the Inter-glacial Beds falling seaward from 80 feet at Kilham and Nafferton, to 25 feet near Kelk, and further east it descends still lower. At Brigham its height is 25 feet, but a mile east it has sunk beneath the marsh. At Brandsburton it is also about 25 feet, but a well at Catfoss proves the base of the Gravel to be there only about high-water level, and consequently considerably beneath the marsh. Still further east, at Seaton, the Gravel disappears altogether,—partly from erosion, but probably largely from a still further dip. At Hornsea a thick bed of sand and gravel occurs below the sea-level, between two Boulder Clays, but this only having been proved by boring it is unsafe to correlate it with the Marine Bed. The borings made by Prof. Prestwich and Mr. Smith at Kelsey Hill prove that there the base of the Gravel is at least 30 feet below the sea-level. South of the Humber the seaward dip is also very marked, but from the absence of levels it is impossible to give accurate heights. In Grimsby the base is just above mean tide level.

The Inter-glacial submarine contours of the district may, therefore, point to a sea gradually deepening eastward and away from the shore. But Messrs. Wood and Rome correlate the Marine Gravels with a bed seen near the top of the cliff along great part of the coast.* This would necessitate an abrupt rise of the seabottom a few miles from the old shore, and the existence of a long bank of undenuded Boulder Clay. A structure of this sort seems quite contrary to the general bearing of the evidence, and scarcely possible. It appears much safer to consider that the known easterly dip continues, and carries the fossiliferous beds out of sight beneath the sea-level. In this way also we can account for what, on the other theory, seems so inexplicable,—the sudden change of Gravels very fossiliferous inland to Gravels in the cliff utterly devoid of fossils. They are not contemporaneous, but of quite different ages.

Whether in the coast section the horizon of the Marine Gravels ever appears above the sea, except at Bridlington, is very doubtful. It is possible that the "red band" may represent it, or the laminated clay above the "Basement Clay," but the balance of the evidence seems in favour of its being older than either. This, however, is a point which must be left for future workers, for the wells which ought to settle the question have none of them been sufficiently carefully examined to allow of correlation of the beds, and in none has the fauna of the Marine Gravels been recog-

* "On the Glacial and Post-glacial Structure of Lincolnshire and South-east Yorkshire."—*Quart. Journ. Geol. Soc.*, vol. xxiv. p. 146.

nized, or, in fact, has any fauna been recorded, except the vague note of "marine shells."

The old upland valleys are still very imperfectly known, and the Inter-glacial deposits in them are sometimes difficult to distinguish from later beds. The Dale which runs from Brocklesby Station, through Croxton and Kirmington, to Somerby Dolter, and thence to the watershed near Owmyb Mill, may be taken as a good example of these valleys. At first sight the present physical geography of the Croxton Dale made it appear to be an old strait connecting Holderness with the Ancholme Valley; but closer examination showed that the watershed must have been considerably higher when the Marine Gravels were deposited, and that the Barnetby Beck has cut back till it has breached the side of Kirmington Vale, and made a pass through the Wolds. The old fiord, instead of passing from Croxton to Melton Ross, turned southward to Kirmington Vale, from which point it is continued for several miles into the Wolds as a dry upland valley. With a submergence of nearly 100 feet, however, the line of saturation in the Chalk would rise; and this valley, and other similar Chalk Dales now quite dry, would contain running streams.

The physical geography of this Inter-glacial Period must have been very different from what at present obtains. With a submergence of 100 feet, if the valleys of the Ancholme and Derwent were cut to anything approaching their present depth, the Yorkshire and Lincolnshire Wolds must have formed two large islands separated by a narrow strait, and the Oolitic hills would form other islands. In fact, a map of the East of England at that Period, divided into several islands cut up by fiords, would look more like the Danish archipelago than anything now existing in Britain.

NATURAL HISTORY.

Turning now to the Natural History of the Period, the first thing that strikes one is that the marine fauna, contrary to what has sometimes been stated, is by no means a poor one; especially when the very imperfect search is borne in mind. Unfortunately, the faunas of only two classes of sea-bottom are represented,—tidal warp, and shifting banks of sand and shingle, formed, as already mentioned, in a depth of from 1 to 15 fathoms. No still-water deposits of any sort are yet known. Taking this into account, and comparing the list of shells with lists of recent species dredged in similar localities, the Inter-glacial fauna is fairly prolific, and a few days search in a large pit like the new one at Kelsey Hill would undoubtedly yield many additions to the list.

Looking at the species already known from the Marine Beds, it is clear that such a fauna must have needed time to migrate into the district. In the early stages, after the retreat of the ice, we should expect to find only a few readily dispersed forms, which would occupy the seas in vast numbers,—just as after a forest fire in America the growth belongs almost entirely to a few

species of trees, and many years must elapse before we again find the varied flora of the ancient forests.

Of mollusca 21 species were added to the list in the course of the Geological Survey, raising the total number known to 61. The general character of these may be described as slightly northern, but not arctic. No exclusively southern forms are included in the list, but 10 or 12 of the species do not now range so far south as the southern half of the North Sea. The rest, with two exceptions, are living British forms, many of which do not extend far north. Of the two exceptions one, *Tellina obliqua*, is an extinct Crag shell, of which a single valve was found at Laceby. It is interesting as being the only extinct species of mollusc yet known from this horizon.

The other exception is the fresh-water *Corbicula (Cyrena) fluminalis*, so abundant at Kelsey Hill, but now extinct in Europe, though living in the Nile and various rivers of Asia. The distribution of this shell is curiously partial; for, though occurring in thousands at Kelsey Hill and the neighbourhood, it is only found at one other locality in the district,—in the sand-pit at Croxton. A glance at the map will at once show the reason of this. Kelsey Hill is exactly opposite the old mouth of the Humber, and would be fully exposed to the strong tides which sweep in and out of an estuary. Croxton is near the head of a fiord which is continued for several miles into the Wolds as an upland valley. The abundance of *Corbicula fluminalis* in marine beds, both in Holderness and in the Fenland, must not be taken as indicating an estuarine habitat. The shell is exceptionally hard and tough, and will stand a great deal of knocking about; in fact, the texture is so compact that allied species are commonly used as knives in certain parts of India. No other fresh-water shells have yet been found at any of the fossiliferous localities in Holderness, except a single specimen of *Bythinia* from Kelsey Hill, which, not being found actually embedded in the sand, has been omitted from the list as possibly recent.

For comparison with the Holderness fauna, a column has been added to the table showing the marine mollusca found at March, in the Fenland. The lists are so similar, that it is probable that Mr. S. V. Wood is correct in correlating the deposits; for it is difficult to understand how, if two distinct Periods are represented, they could yield faunas so nearly identical. At present the marine mollusca of March are too imperfectly known to allow us to speak with certainty, but the slight differences seem only such as would be found in two distinct bays in the same sea.

The Post-glacial date of the March Gravels is sometimes inferred from the absence of any Boulder Clay over them. But negative evidence is of little value, for the majority of the Holderness sections show no overlying Boulder Clay; and at Little Bytham, not far from the Fenland, Mr. Skertchly records *Corbicula fluminalis* and *Tellina balthica* from beneath Boulder Clay. The Gravels near March cap isolated hills of Kimeridge Clay or Boulder Clay, rising through the fens, and seem to be outlying

portions of a much-denuded sheet, which covered the old floor of the Fenland before it had been lowered beneath the present sea-level. In fact, with the exception of the local absence of the overlying Boulder Clay in the southern area, the structure of the Fenland seems identical with that of the country near the Humber.

With the Bridlington Crag, notwithstanding the close proximity of the deposits, the Marine Gravels show little connection, only about half the species in the latter being found at Bridlington, though the Bridlington shells are now well known. The so-called "Middle Glacial Sand" of Yarmouth seems also very different, and the fauna of an older type than that of the Marine Gravels of Holderness.

Thus southward the only deposit containing a similar assemblage of mollusca is the Marine Gravel of the Fenland. Northward there is an ancient littoral deposit in Speeton Bay which agrees so well in position, and in fauna as far as yet known, that there is every probability of its turning out to be a continuation of the same bed.* It consists of silty sand and mud, very similar to that of Kirmington, at a height of 105 feet above the sea. The few shells known are all, with the exception of *Utriculus obtusus*, Holderness species; and the *Utriculus* is a thin-shelled mud-loving species, which in Holderness we could only expect to find at Kirmington. Further north the fauna of the Inter-glacial Beds is too imperfectly known to allow of any correlation.

Of the other classes of fossils little can be said, they are so imperfectly known. The Foraminifera have only been collected at Kirmington, as few were seen in the Gravels, and those were too much worn to be worth preserving. Mr. H. B. Brady, who has kindly examined them, determines 15 species from Kirmington, and writes that "certainly more than 90 per cent. of the specimens are *Nonionina depressula*—an essentially shallow-water species. The species and the appearance of the specimens alike indicate a starved shallow-water fauna."

The mammals, which have been determined by Mr. E. T. Newton, like the mollusca, are northern, but not decidedly Arctic. The occurrence of the reindeer and walrus points, at any rate, to cold winters, but the bison and leptorrhine rhinoceros seem to indicate that the climate cannot have been very severe. The horse has only yet been found at Hessle, and the Irish elk at Bridlington.

FOSSILS OF THE MARINE INTER-GLACIAL BEDS.

PLANTÆ.	Locality.
<i>Phragmites communis</i> , <i>Trin.</i>	Kirmington.
<i>Scirpus fuitans</i> ? <i>L.</i>	"

* See also Phillips, "Geology of Yorkshire," Part I., 3rd edit. p. 100; and G. W. Lamplugh, *Geol. Mag.*, dec. ii. vol. viii. p. 174.

FORAMINIFERA*. (Determined by Mr. H. B. Brady, F.R.S.)

Locality.			
<i>Lagena levis</i> , <i>Mont.</i>			Kirmington.
— <i>clavata</i> , <i>D'Orb.</i>	—	—	”
— <i>globosa</i> , <i>W. & J.</i>	—	—	”
— <i>distoma</i> , <i>P. & J.</i>	—	—	”
— <i>semistriata</i> , <i>Will.</i>	—	—	”
— <i>striata</i> , <i>W. & J.</i>	—	—	”
— <i>squamosa</i> , <i>Mont.</i>	—	—	”
— <i>levigata</i> , <i>Reuss.</i>	—	—	”
<i>Nodosaria</i> (D.) <i>brevis</i> , <i>D'Orb.</i>	—	—	”
<i>Polymorphina</i> <i>lactea</i> , <i>W. & J.</i>	—	—	”
— <i>oblonga</i> , <i>D'Orb.</i>	—	—	”
<i>Nonionina</i> <i>depressula</i> , <i>W. & J.</i>	—	—	”
<i>Polystomella</i> <i>striatopunctata</i> , <i>F. & M.</i>	—	—	”
— <i>crispa</i> , <i>Linn.</i>	—	—	”
ECHINODERMATA.			
<i>Amphidetus</i> , spines	—	—	Kirmington.
CIRRIPEDIA.			
<i>Balanus crenatus</i> , <i>Brug.</i>	—	—	Kelsey Hill, Claythorpe.
— <i>Hameri</i> , <i>Asc.</i>	—	—	Kelsey Hill.
— <i>porcatus</i> , <i>Da C.</i>	—	—	Kelsey Hill, Laceby, Claythorpe.
ENTOMOSTRACA. (Determined by Dr. G. S. Brady, F.R.S.)			
<i>Cythere pellucida</i> , <i>Baird</i>	—	—	Kirmington.
— <i>castanea</i> , <i>G. O. Sars.</i>	—	—	”
DECAPODA.			
Crab claw	—	—	Croxton.

Authorities: C.=Mr. Cordeaux. H.=Mr. Harmer. J.=Dr. Jeffreys. R.=Reid.
W.=Mr. S. V. Wood.

	Kelsey Hill.	Croxton.	Kelby.	Laceby.	Great Coates.	By Grove.	Claythorpe.	March (Cambridge-shire).	Remarks.
BRACHIOPODA.									
<i>Rhynchonella psittacea</i> , <i>Chemn.</i>	•	•	•	•	•	•	•	•	H., R.
CONCHIFERA.									
<i>Anomia ephippium</i> , <i>L.</i>	—	Leck.	?	R.	•	•	•	•	R.
<i>Astarte borealis</i> , <i>Chemn.</i>	—	J.	R.	•	R.	•	•	•	H., R.
— <i>compressa</i> , <i>Mont.</i>	—	J.	R.	•	R.	•	•	•	H.
— <i> sulcata</i> , <i>Da C.</i>	—	•	R.	•	R.	•	•	•	H.
<i>Cardium echinatum</i> , <i>L.</i>	—	J.	R.	R.	R.	C.	R.	R.	
— <i>edule</i> , <i>L.</i>	—	J.	R.	R.	R.	C.	R.	R.	H., R.
— <i>exiguum</i> , <i>Gmel.</i>	—	R.	R.	R.	R.	C.	R.	R.	Very rare.
<i>Corbicula fluminalis</i> , <i>Müller</i>	J.	R.	R.	R.	R.	R.	R.	R.	Plentiful locally. = <i>C. striata</i> = <i>C. nucicula</i> .
<i>Corbula gibba</i> , <i>Oliv.</i>	J.	R.	R.	R.	R.	R.	R.	R.	

* A few large Foraminifera occur in the sand at Laceby, but they are too much worn to be worth collecting.

	Kelsey Hill.	Croton.	Keely.	Lacey.	Great Coates.	Ruby Grove.	Claythorpe.	March (Cambridgeshire).	Remarks.
<i>Cyprina islandica</i> , <i>Lam.</i>	-	J.	R.	R.	C.	R.	R.	H.	
<i>Cytherea Chione</i> , <i>L.</i>	-	R.	R.	R.	R.	.	.	.	One broken valve.
<i>Donax vittatus</i> , <i>Da C.</i>	-	R.	R.	R.	C.	.	.	.	Rare but perfect.
<i>Loripes divaricata</i> , <i>L.</i>	-	J., R.	R.	R.	C.	R.	R.	H., R.	Including var. <i>ovalis</i> .
<i>Mactra solida</i> , <i>L.</i>	-	J., R.	R.	R.	C.	R.	R.	H.	
— <i>subtruncata</i> , <i>Da C.</i>	-	J., R.	R.	R.	C.	R.	R.	H., R.	
<i>Mya arenaria</i> , <i>L.</i>	-	J., R.	R.	R.	R.	.	R.	H.	
— <i>truncata</i> , <i>L.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
<i>Mytilus edulis</i> , <i>L.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
— <i>modiolus</i> , <i>L.</i>	-	J., R.	R.	R.	R.	.	R.	H.	
<i>Nucula nucleus</i> , <i>L.</i>	-	J., R.	R.	R.	R.	R.	R.	H.	
<i>Ostrea edulis</i> , <i>L.</i>	-	J., R.	R.	R.	C.	R.	R.	H., R.	
<i>Pecten islandicus</i> , <i>Müller</i>	-	R.	R.	R.	C.	R.	R.	H., R.	
<i>Pholas crispata</i> , <i>L.</i>	-	J., R.	R.	R.	C.	R.	R.	H., R.	
— <i>dactylus</i> ? <i>L.</i>	-	J., R.	R.	R.	C.	R.	R.	R.	
<i>Psammodius ferrugineus</i> , <i>Chemn.</i>	-	J., R.	R.	R.	C.	R.	R.	H.	
<i>Saxicava arctica</i> , <i>L.</i>	-	R.	R.	R.	R.	.	R.	H., R.	
<i>Scrobicularia plana</i> , <i>Da C.</i>	-	R.	R.	R.	R.	.	R.	H., R.	
<i>Solen siliqua</i> ? <i>L.</i>	-	R.	R.	R.	R.	.	R.	H.	
<i>Tapena decussata</i> , <i>L.</i>	-	R.	R.	R.	R.	.	R.	H.	
<i>Tellina balthica</i> , <i>L.</i>	-	J., R.	R.	R.	C.	R.	R.	H., R.	
— <i>calcaria</i> , <i>Chemn.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
— <i>obliqua</i> , <i>J. Sow.</i>	-	J., R.	R.	R.	R.	.	R.	H.	
— <i>tennis</i> ? <i>Da C.</i>	-	J., R.	R.	R.	R.	.	R.	Wood	
<i>Venus gallina</i> , <i>L.</i>	-	J.	R.	R.	R.	.	R.	R.	
SOLENOCONCHIA.									
<i>Dentalium entalis</i> , <i>L.</i>	-	J., R.	R.	R.	C.	R.	R.	R.	
GASTROPODA.									
<i>Aporrhais pespellicani</i> , <i>L.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
<i>Buccinum undatum</i> , <i>L.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
<i>Emarginula fissura</i> , <i>L.</i>	-	J., R.	R.	R.	R.	.	R.	R.	
<i>Hydrobia ulvae</i> , <i>Pen.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
<i>Lucuna crassior</i> , <i>Mont.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
— <i>vincta</i> , <i>Mont.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
<i>Littorina littorea</i> , <i>Linn.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
— <i>rudis</i> , <i>Maton.</i>	-	J.	R.	R.	R.	.	R.	H.	
— <i>squilda</i> , <i>B. & S.</i>	-	J.	R.	R.	R.	.	R.	H.	
<i>Murex erinaceus</i> , <i>L.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
<i>Nassa reticulata</i> , <i>L.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
<i>Natica Alderi</i> , <i>Forb.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
— <i>catena</i> , <i>Da C.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
— <i>clausa</i> , <i>B. & S.</i>	-	J.	R.	R.	R.	.	R.	H.	
— <i>greenlandica</i> , <i>Beck.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
— <i>islandica</i> , <i>Gmel.</i>	-	J.	R.	R.	R.	.	R.	H.	
<i>Odostomia rufa</i> , <i>Phil.</i>	-	J.	R.	R.	R.	.	R.	H., R.	
<i>Pleurotoma nebula</i> , <i>Mont.</i>	-	J.	R.	R.	R.	.	R.	H., R.	
— <i>pyramidalis</i> , <i>Strom.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
— <i>rufa</i> , <i>Mont.</i>	-	J.	R.	R.	R.	.	R.	H.	
— <i>turriola</i> , <i>Mont.</i>	-	J., R.	R.	R.	C.	.	R.	H., R.	
<i>Purpura lapillus</i> , <i>L.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
<i>Rissoa labiosa</i> , <i>Mont.</i>	-	J.	R.	R.	R.	.	R.	H., R.	
<i>Scalaria communis</i> , <i>Lam.</i>	-	R.	R.	R.	R.	.	R.	H., R.	
<i>Trochus cinerarius</i> , <i>L.</i>	-	R.	R.	R.	R.	.	R.	H., R.	
<i>Trophon antiquus</i> , <i>L.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	
— <i>Bamfus</i> , <i>Mont.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	= <i>T. truncatus</i> .
— <i>gracilis</i> , <i>Da C.</i>	-	J.	R.	R.	R.	.	R.	H.	= <i>T. clathratus</i> .
— <i>scalariformis</i> , <i>Gould</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	= <i>T. communis</i> .
<i>Turritella terebra</i> , <i>L.</i>	-	J., R.	R.	R.	R.	.	R.	H., R.	= <i>V. gonata</i> .
<i>Velutina undata</i> , <i>J. Smith</i>	-	J.	R.	R.	R.	.	R.	H.	

PISCES.**Locality.**

Vertebræ, undetermined - - - - - Kelsey Hill.

MAMMALIA. (Determined by Mr. E. T. Newton.

<i>Elephas primigenius</i> , <i>Blumb.</i>	-	-	-	-	Kelsey Hill, Brandsburton.
<i>Cervus tarandus</i> , <i>L.</i>	-	-	-	-	"
<i>Bison priscus</i> , <i>Boj.</i>	-	-	-	-	"
<i>Rhinoceros leptorhinus</i> , <i>Cuv.</i>	-	-	-	-	"
<i>Trichechus rosmarus</i> , <i>L.</i>	-	-	-	-	"

CHAPTER VII.

POST-GLACIAL DEPOSITS.

The beds immediately succeeding the Boulder Clay are, perhaps, less understood than any other Pleistocene Deposits, and the classification here adopted must be regarded as merely provisional. Unfortunately in this district there is little evidence of the actual superposition of one Post-glacial bed upon another, and one is forced to rely largely upon the general structure of the country, to show which is of the earlier date. Two distinct episodes in the Post-glacial Period are apparently represented; and these correspond closely with changes which we know occurred in other parts of the East and South of England.

After the retreat of the ice, the level of the sea, for a time at least, was about 40 feet higher than at present, and the well-known raised "beaches" were formed. Of these marine beaches there is now no relic in the district described in this Memoir; denudation proceeds so rapidly that every trace of them has long ago been swept away. Often in the sheltered bays of a rocky coast they are still to be found, but the only portions preserved in the East of England appear to be at Saltburn, and perhaps at Hunstanton. At both these places the maximum height of the beach above the present high-water level is about 40 feet. Notwithstanding the absence of raised beaches in Holderness, of indirect evidence of the submergence there appears to be no want; and to this period should probably be referred various deposits which, differing entirely in lithological character, appear to agree in requiring for their formation a lower level of the land.

Mr Dakyns thus describes the sections in the northern part of the district:—

"At Bridlington Quay the purple Boulder Clay is directly overlaid by a set of beds consisting of sand and gravel and laminated clay. Immediately north of the town, for the distance of about half a mile, the cliff is low, being perhaps thirty feet above mean tide level. Along this portion of the cliff, the Gravel, which immediately overlies the Boulder Clay and consists principally of Chalk pebbles, is crushed and contorted in the strangest fashion. It contains included masses of Boulder Clay, and has tongues of Boulder Clay intruded into its midst. The surface of the Boulder Clay is very irregular, and in a manner that cannot be due to mere aqueous erosion. Thus, wherever there is a vertical wall of Boulder Clay, the Gravel beds are vertical too; and where there is an intruded tongue of Boulder Clay, the beds of gravel are bent round conformably to the shape of the intruded mass, while at other places all traces of bedding are lost in the general confusion. It is obvious that after or during the deposition of the Gravel in regular layers, some force, doubtless that due to masses of ice in motion, has crushed the Clay and Gravel together. These Gravels, therefore, though posterior to the

great mass of Boulder Clay, must be of Glacial age.* In these Gravels Mr. Lamplugh has found *Limnaea peregra* in layers of sandy clay, so that they are, probably, as their chalky character would itself suggest, old river Gravels.† In Gravels at Pocklington, of a like character and occupying a similar position as regards the surrounding country, we also found fresh-water shells in marly seams. Similar Gravels at Driffield, which cannot be well separated from the valley Gravels, are equally mixed up with Boulder Clay. In fact, the general appearance at Bridlington lends confirmation to the idea that there is a general passage back by way of old river Gravels into Glacial Beds."

"At Potter Hill the cliff rises to over fifty feet above mean tide level, and continues to rise by steps to Sewerby Park. Along this part of the cliff the Gravels overlying the Boulder Clay are similar in lithological character to those last described; but exhibit a striking contrast in this, that they are as a rule evenly bedded and free from contortions or intrusion of Boulder Clay, although there are in one or two places such contortions and dovetailing of Gravel and Boulder Clay in the lower part of the Gravel, so that we cannot separate the one from the other."

"As we go eastward a band of Gravel, consisting mainly of drift pebbles, and lying in undulating layers, comes in between the Boulder Clay and the evenly bedded chalky Gravel. This is probably the tail end of the Drift Gravel that overlies the Boulder Clay at Danes Dike. On the south side of the town the cliff corresponds to that on the north side; and the shape of the ground suggests that the two were once continuous. The section here is as follows: at the bottom Boulder Clay overlain by Gravel, not continuous but lying in hollows in the Boulder Clay; over this Gravel and Boulder Clay we have beds of finely laminated sandy Clay (Warp of Prof. Phillips) beautifully ripple-marked, passing into Sand northwards; then Sand; and at the top very fine chalky Gravel. The bottom Gravel has a Glacial look; and, near Applepie Cottage, where the greater part of the beds forming the cliff have been denuded and replaced by recent fluviatile and lacustrine deposits, the small portion left of the older beds, consisting of Gravel and Sand, partly abuts against a wall of Boulder Clay, and partly is overlaid by Boulder Clay."

"Among the beds of Warp and Sand there are no signs of glacial action, unless the crumpling of the laminae of Warp at one spot, and at another the presence of a large erratic apparently embedded in fine Sand and Warp, be taken as such."

"In the Sand over the Warp there is a band of queer convolutions lying along a definite horizon. They are generally exactly like concretions in sandstone, or rather incipient concretions, and such they probably are."‡

* See, however, p. 76.

† *Proc. Geol. Soc. Yorkshire*, n.s., vol. vii. p. 389.

‡ *Proc. Geol. Soc., Yorkshire*, n.s., vol. viii. p. 32 and Plate.

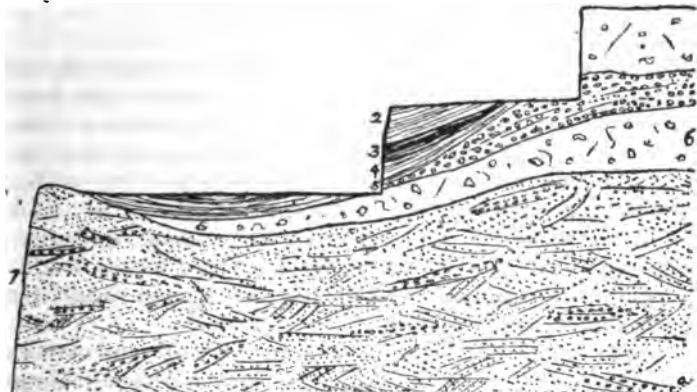
Southward no other sections of beds which can with any probability be referred to this horizon are seen till Easington is reached. Here, due east of the town, the cliff is about 30 feet high, and is capped by eight feet of Laminated Clay, with a gravelly base containing derivative fragments of shell. In the highest part of Kilnsea Cliff there is an outlier of similar beds, but here the cliff is less than 20 feet high. Both these patches are small; and the Clay is so like the matrix of the Boulder Clay, and there is so much stony soil derived from the Boulder Clay over them, that it was found quite impracticable to follow the boundaries inland, especially as there is no feature. In both cases the exposures agree in showing Laminated Clays of similar character. They look very like estuarine or lacustrine beds; but the absence of fossils in this matrix is difficult to understand, and reminds one of the unfossiliferous ripple-marked Laminated Clays so commonly intercalated in the Boulder Clay. Possibly they were formed immediately on the retreat of the ice; or they may really belong to the Glacial Beds, an overlying Boulder Clay having, in these cliffs, been entirely denuded.

South of the Humber there is shingle near Barton, which, though coloured on the map as Glacial, has very much the look of a raised estuarine beach. The same beach can be followed, though perhaps not continuously, round the escarpment of the Chalk to beyond Horkstow. Not rising more than 50 feet above the sea, it forms for several miles a terrace at the foot of the Wolds.

These Gravels and Laminated Clays all appear to have been deposited when the present valleys in the Boulder Clay had no existence, or rather had only been outlined. They seem also to have been formed with the sea at a higher level than at present, for the Clays were clearly deposited in nearly still water, and lakes could scarcely exist so much above the sea level within a short distance of the coast. It is, however, not necessary to consider all the deposits to be exactly contemporaneous, or formed with the same amount of submergence; there was probably a gradual change of level.

Crossing the Humber again, there is one deposit, which from its peculiar position can only be referred to this period of submergence. This is a peaty fresh-water bed, occurring in what at first seems a most unlikely place,—the top of an isolated sand-hill rising boldly 40 feet out of the marsh. The cross section shown in Fig. 8 is constructed from faces exposed in the new pit at Kelsey Hill during May 1884. At the time of my first visit the peaty clay had been cut back just beyond the deepest part of the hollow; on the second visit the faces were in the position noted. A few days later, and the evidence would probably be entirely destroyed, though fresh deposits might be cut into.

Over the Inter-glacial Sands and Gravels there is a very irregular capping of Boulder Clay, which has subsided into hollows, perhaps through the slipping of the sand when saturated with water. In one of these there is a fresh-water deposit, apparently formed in a pond about 50 feet wide in each direction. The peaty clay is full of

FIG. 8.—*New Pit at Kelsey Hill*.—Cross section.

1 Stony brick-earth.	5 Earthy gravel.
2 Blue clay.	6 Boulder Clay.
3 Peaty bed.	7 Marine gravel.
4 Blue clay.	

plant remains and elytra of beetles, including a *Donacia*, which does not quite agree with any species known to Mr. C. O. Waterhouse, and a *Gyrinus* only determinable generically. It also yielded the much decayed wing-bone of a large bird. But all other calcareous fossils have disappeared, though the occasional occurrence of the insoluble portion of the fruit of *Chara* shows that both it and shells may once have been abundant. The few plants determined throw no light on the climatic conditions. They were the pond-weed, reed, and water-crowfoot, all species having a wide range. Overlying the clay there is coarse unstratified gravel, which at one point appears to be banked against a vertical wall of Boulder Clay. When the gravel rests directly on the disturbed Marine Beds it is not easy to distinguish them; and this may account for the curious appearance of the southern end of the section, where the unstratified gravel looks almost as if it passed under Boulder Clay, though everywhere else it distinctly overlies it. Capping the hill, and resting indiscriminately on any of the beds, is a stony loam, with joints weathering green and mottled. At first this was taken to be a Boulder Clay, but closer examination showed that it was only a reconstructed bed, being full of small roots from top to bottom.

This Fresh-water Bed must have been formed when the submergence was about 40 feet, for it rests partly on porous gravel, and water could not remain in the pond unless the line of saturation were 40 feet higher than now. The coarse gravels also show the agency of running water; yet Kelsey Hill is now considerably the highest point in the neighbourhood, and the lower area with which it is connected is almost an island. On three sides it is surrounded by marshes at the sea level, and on the fourth by a low tract of land, not more than ten feet above the sea, through which the Junction Drain has been carried. It seems, therefore,

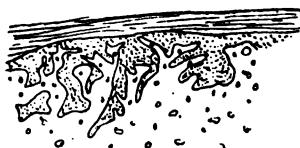
that not only has the sea-level altered, but many of the valleys in the Boulder Clay have been cut since the period of the Raised Beaches.

In certain of the dry Chalk valleys there occur gravels which are so considerably above the level of any springs now flowing, even during the wettest season, that they are sometimes referred to a special "Pluvial Period." Instead of bringing into play a cause of which, in this district at least, there is no other evidence, it seems much simpler to refer most of these gravels to the date of the raised beaches. This will account without difficulty for their position; for the line of saturation in the Chalk would be raised nearly 40 feet, and consequently the springs would break out much higher up the Dales.

The curious way in which Fresh-water Gravels and Alluvium are often contorted together, and into the underlying Boulder Clay, is very puzzling; and, like Messrs. Dakyns and Lamplugh, I have generally referred the contortion to glacial action. But a closer study of the origin of soils and of the weathering of rocks suggests a much simpler explanation, and one more in accord with the appearance of the fossils contained in the contorted beds, which are not usually markedly northern.

Boulder Clays underlying old raised Alluvium are nearly always much weathered, and often have the Chalk dissolved out to a depth of several feet. If this abstraction of the calcareous matter proceeded quite uniformly over the whole surface, there would be merely a regular subsidence of the overlying bed. But we find that in all calcareous rocks the percolating rain-water tends to make its way downwards along definite lines, and form channels or "pipes," into which the overlying soil or Alluvium gradually subsides. To this rule Boulder Clays are no exception; and through the phenomenon is much more marked and unmistakable in the very marly Boulder Clays of Norfolk and Suffolk, yet it seems almost equally common, though on a smaller scale, in Holderness. To this cause may perhaps be referred some of the contortions shown in Figs. 3, 8, and 9, and not necessarily to any glacial action.

FIG. 9.—*Contorted Boulder Clay and Gravel near Bridlington.*
(G. W. Lamplugh, *Proc. Geol. Soc., Yorkshire, n.s.*, vol. viii. p. 27).



While on the subject of solution of calcareous matter by rain-water, it may be well to draw attention to another obscure phenomenon easily accounted for through this agency. This is the upright position—with the longer axes vertical—often taken by the flints in unstratified and contorted Post-glacial Gravels.

In Holderness this is not very often seen, but in Norfolk and most Chalk districts it occurs so commonly as to appear the normal arrangement of the stones. For example, a large pit near Burnham Market, in Norfolk, shows a deep section of false-bedded very chalky Gravel; but this Gravel has suffered from weathering to such an extent that all the chalk has disappeared from large irregular pipes. This slow and irregular removal of half the bulk has obliterated all the bedding in the upper part, and allowed the flints to subside. In subsiding each stone has descended with its longer axis vertical. Unfortunately, in Holderness no section was noticed in which the line between the weathered and unweathered Gravel was conspicuous, and the process could be traced step by step as at Burnham. The lesser quantity of chalk contained in the Holderness Gravels also makes the upright position of the stones less marked and common than in many other districts.

CHAPTER VIII.

POST-GLACIAL BEDS—*continued.*

The downward movement described in the last Chapter appears to have given place to upheaval: the land rose till its level was at least 50 feet higher than now, and deep valleys were cut in every direction through the Boulder Clay. The "Submerged" or rather "Buried Forests" so often found in wells, or at the bottom of docks in the Humber, at a depth of nearly 50 feet below high-water, prove that, even allowing for compression and consolidation of the peat and underlying beds, there must have been an elevation to fully that extent. But of any greater elevation there is no evidence in the district under consideration.

Of deposits formed when the land was rising we know nothing. In this district the period is apparently only represented by denudation—unless some of the Gravels in the dry Chalk valleys partially fill the gap. While the elevation was about 50 feet the lowest of the Buried Forests grew on a wide alluvial flat which fringed the Humber and Lincolnshire coast, and probably also the coast of Yorkshire, though there it has since been entirely destroyed. Subsidence of the land, or rise of the sea-level, submerged the Forest, and allowed a considerable thickness of estuarine warp to be deposited on it. But this subsidence was apparently not quite continuous, for there is a second Buried Forest at about the present low-water level. This latter is the ordinary "Submerged Forest" seen on the foreshore. More than two of these old land surfaces can seldom, if ever, be found in one section; and though it is unsafe yet to speak with any confidence on the point, the thick bed of marine warp between them is very suggestive of a subsidence too rapid to allow deposition to keep pace with it, and raise the surface above the ordinary water level.

Another result of this subsidence was to turn the smaller valleys first into salt-water creeks, and then, by the irregular deposition of banks of mud and sand in their channels, to divide them into chains of fresh-water meres connected by streams, like the "broads" of Norfolk. These meres and broads are rapidly silting up, the one at Hornsea being the last remaining in Holderness, though there is abundance of evidence of the former existence of a much larger number. No doubt in part the disappearance of the meres is due to artificial drainage, but an examination of the deposits shows that the filling up is almost entirely natural; drainage has only put the finishing touch, and converted into pasture land a mere already shallowed to a reedy swamp.

The Valley Gravels, Lacustrine Marls, Old Warp, and Buried Forests, though so different in lithological character, probably nearly all belong to this period of gradual subsidence. Close examination shows no hard and fast line between them, but often a clear alternation. Unfortunately the exact succession of the minor divisions is still too doubtful to allow of any but a geographical classification. Though we can be quite sure that forests of oak did not flourish in the district at the same time that beds full of leaves of the arctic birch were being deposited, yet it is at present often impossible to say which was of earlier date.

Commencing, as a matter of convenience, with the lacustrine beds on the coast, we find on both sides of Bridlington Quay that channels or hollows have been cut through the Gravels mentioned in the last Chapter, and in these hollows have been deposited bedded fresh-water Marls. So full a description of these beds at Bridlington will be found in Mr. Lamplugh's papers,* that it is unnecessary here to give the details, especially as very few fossils are yet recorded. These Marls rest on low level sand, gravel, and silt, which Mr. Lamplugh considers to be closely connected with them, and perhaps to be formed contemporaneously. But the whole of the deposits are newer than the high-level Gravels of Sewerby and Bridlington already described, and are separated from them by a line of erosion which often cuts deeply into the Boulder Clay. At the south end of the town, in one of these hollows in Boulder Clay filled with peaty marl, Dr. Nathorst discovered leaves of the arctic birch (*Betula nana*, L.), but no further progress has yet been made in collecting the plants of this interesting deposit.†

Another of these lacustrine deposits, seen at Skipsea, is thus described by Prof. Phillips:—‡

"Its length is about a quarter of a mile; its extreme elevation above high water, at the south extremity, is 12 feet, but in the

* *Op. cit.*, Parts. I. II. and III.

† "Über neue Funde von fossilen Glacialpflanzen."—*Engler's botanischer Jahrbuch*, 1881, p. 481."

‡ *Geology of Yorkshire*, Part I. pp. 80, 81.

middle only 4 or 5 feet. The series of depositions from fresh water is as follows :—

“ Peat, with roots, branches, and hazel-nuts : its utmost thickness is 7 feet ; where this happens the lower 4 feet 6 inches are solid, and break like clay ; the upper part is then fibrous. Yellowish clay, full of *Bithynia tentaculata*, *Cyclas cornea*, *C. lacustris*, and a few specimens of *Limnea stagnalis* : this is seen only on the southern side of the hollow. Blue clay, full of *Cyclades* ; here is some phosphate of iron ; this rests upon gravel, under which is blue or brown Boulder Clay.”

“ In this deposit an old man, who was employed in collecting gravel, accidentally discovered the head and antlers of *Cervus megaceros*. . . . Subsequently the lower jaw was discovered by the researches of Mr. Arthur Strickland.”

Opposite Atwick there is another old mere, in the centre of which measurements by Mr. Dakyns give :—

	FEET.
Cubical grey Clay	6
Peaty layer	—
White Marl	1
Sand and Gravel	10
Red Boulder Clay	—

Prof. Phillips states that an elephant's tusk of extraordinary dimensions was found at this place.

At Hornsea we find the most extensive lacustrine deposit in Holderness ; and as it is very well shown, and is clearly connected with the still existing mere, it will be described fully. Hornsea Mere is a sheet of water, now a mile and a half long by half a mile wide, and with its bottom in places below high water. Even while at its present level, it was formerly more extensive, the marshy ground of Wassand Mere forming part of it. South of the village of Hornsea there is also a low alluvial flat which has evidently been the floor of another old mere, though the encroachments of the sea, and an artificial channel through the sand dunes, have now drained it. This mere was only separated from the present one by a narrow ridge of gravel.

But, besides these low alluvial flats, all round the Mere there is a distinct terrace at about 10 feet above the present water level, bounded by a steeper slope of Boulder Clay. This terrace is sometimes merely a feature in the Boulder Clay, though usually there is a considerable amount of gravel on it. That it marks a former level of the lake, and that the gravel is an old lacustrine deposit, is proved by the occasional occurrence in it, not far from its highest limit, of fresh-water clay and marl. The village of Hornsea is built on a continuation of the same sheet of gravel which, north of the town, reaches a height of 30 feet above high water. From the large spread these lacustrine beds still make, and the fact that they extend to the coast without any sign of narrowing, the Mere must once have been several times its present size, and from 10 to 20 feet deeper. Even without allowing for the part lost by marine denudation, the old lake would measure two-thirds of a mile wide by at least 3 miles long.

Where all this mass of gravel came from is not clear, for the streams running eastward are not large, and the watershed is now close to the head of the old lake. The drainage area of Hornsea Mere is now only about 8 square miles, but the Carr Dike appears to be cutting eastward, and perhaps the stream in the valley between Hornsea Mere and Catfoss originally flowed in the opposite direction.

Commencing at the head of the Mere there is a considerable spread of gravel near Wassand, rising in places fully 20 feet above the water. A pit near the keeper's house shows coarse false-bedded gravel of Chalk and other Boulder Clay stones; and south of the house there is another shallow pit in sand. Along the northern margin of the Mere a gravel terrace extends nearly continuously as far as the Hermitage, but the only section is a small pit opposite Lady Island. From this point there is a distinct feature connecting the terrace with the spread of gravel at Hornsea Village, though the gravel itself has either never been deposited, or has been entirely denuded. Along the southern margin of the lake Shell Marl was seen in a new ditch south of the Snipe Ground at a height of about 10 feet above the Mere. The old terrace is considerably wider than the strip of gravel mapped, the feature passing through Great Wassand and keeping above the 25-foot contour line all the way to the coast.

At the Hornsea Bridge Station a section was exposed showing the alternation of the lacustrine Marl with Sand and Gravel. It is now entirely hidden, but Messrs. Wood and Rome, who originally examined it, state that "the intercalated loam with mollusca is seen to be oblique-bedded, with the gravel at a high angle. The mollusca which we have obtained from this deposit are all purely fresh-water forms, existing and common in this country, belonging to the Genera *Limnea*, *Planorbis*, *Bithynia*, *Anodonta*, *Cyclas*, and *Pisidium*; but we were not able to find any traces either of *Cyrena fluminalis* or *Hydrobia marginata*."*

In Hornsea itself there are no open sections of the Gravel, but an old well bored at the New Inn is said to have passed through 161 feet of gravel and sand before reaching the Chalk. It is, however, difficult to say what age this mass of gravel and sand can belong to, and both the details and depth to the Chalk are so unlike any other wells in Holderness as to throw doubt on their accuracy. The section, communicated by the late Mr. Smalley to Mr. S. V. Wood, shows:—

	FEET.
Sand	9
Sand and Gravel, with small shells	52
Warp	4
Sand and Gravel, without shells	100
 To Chalk	 161

* *Quart. Journ. Geol. Soc.*, vol. xxiv. p. 154.

As several borings at Hornsea reached Chalk at 60 or 70 feet below the sea-level, it is possible that a mistake has been made in recording these details.

In the cliff north of the town the Gravel begins as a thin bed close to the 50-foot contour line. Between this point and the Marine Hotel, wherever the sections are clear, Boulder Clay is seen at the base of the cliff; but a good deal of this portion is hidden, and, judging from published accounts, there is a deep channel near the Marine Hotel. The Rev. J. L. Rome observed at the base of the cliff immediately north of the Marine Hotel, in addition to beds of loam intercalated in, and false-bedded with, the gravel, a loam-bed 6 feet thick, occurring beneath the Gravel, containing fresh-water mollusca in great abundance. These beds were observed at two points, dipping in opposite directions, so as to indicate a limited basin of date earlier than the gravel-beds of that locality.* This is apparently the same section that Prof. Phillips again observed in 1872, and of which he gives two sketches showing Gravel and Sand alternating with Warp and fresh-water Marl with *Chara*; but he was unable to find shells. The continuous exposure of peat on the foreshore opposite and north of the Marine Hotel may be connected with this channel, as well as with the main mass at Hornsea Gap, the Boulder Clay hill on which the Hotel is built being only an island in the old Mere. South of Marine Terrace the cliff is low and hidden by Blown Sand, but the foreshore opposite shows excellent sections of lacustrine Clay, Marl, and Peat.

The beds on the foreshore extend for over half a mile, and can nearly always be examined somewhere, though the constant shifting of the beach seldom allows the whole to be seen at once. This deposit may be accepted as a good example of what is ordinarily termed a "submerged forest," for in places roots occur in the clay at the level of extreme low-water. In itself this is scarcely sufficient evidence of submergence, for roots may penetrate much below the sea level, as long as sea-water cannot reach them. At Hornsea no trunks were observed attached to the roots, though they certainly occur at other places on the coast at the same level. The following section was recorded by Prof. Phillips;† it is probably a generalized one, as no exact locality is mentioned:—

	FEET. INCHES.
6. Blue clay-bed; at its base a layer of plants with small pebbles. In it roots and stems, and a remarkable straight piece of fir wood, smoothed to a tapering elliptical section, 5 feet long, were found in the clay.	2 or 3 —
5. Brown clay-bed, unequal. In it shells of <i>Anodon</i> are common, with the epidermis preserved.	1 to 3 —
4. Laminated plant-bed, occasionally peaty -	— 0 to 3
3. <i>Oyclas</i> marls of pale brown tint, mixed with 4. Small <i>Paludinæ</i> [<i>Bithyniæ</i>] occur in abundance.	— 4 to 12

* Wood and Rome, *op. cit.*; and Phillips, *op. cit.*, p. 79.

† *Op. cit.*, pp. 76, 77.

	FEET. INCHES.
2. Peat and black root-bed of irregular thickness } and interrupted extent. } - 0 to 6	
1. Red-brown clay and pebbles (Boulder Clay) - - -	

the beds dipping gently seaward. The continuous exposures examined in the course of the Geological Survey seemed too variable to give any definite succession of the minor divisions, though the general order is very similar to that given by Prof. Phillips. In the peaty clays leaves are common, though not well preserved. All those noticed belonged to Oak, Alder, and Willow. Only a few of the larger seeds were collected, as the plant-bearing beds consist of a tenacious black mud very difficult to wash. Concretions of sand are abundant on certain horizons, and on others there are small lumps and stains of phosphate of iron, or nodules of iron pyrites.

The following list includes all the fossils yet known from this lacustrine deposit at Hornsea. It is taken from the specimens collected in the course of the Geological Survey, the mammals in the Hull and York Museums, and the entomostraca from the Palaeontographical Society's Monograph by Messrs. G. S. Brady, Crosskey, and Robertson.

<i>Chara</i> , sp.	<i>Cyclas cornea</i> .
<i>Pinus sylvestris</i> ?	<i>Pisidium pusillum</i> .
<i>Potamogeton</i> , sp.	<i>Limnæa peregra</i> .
<i>Alnus glutinosa</i> , cones and leaves.	<i>Planorbis contortus</i> . — <i>nautilus</i> .
<i>Quercus robur</i> , leaves and cups.	<i>Bithynia tentaculata</i> .
<i>Salix</i> , sp., leaves.	<i>Valvata piscinalis</i> .
<i>Prunus padus</i> , stones.	<i>Perca fluviatilis</i> .
<i>Cypris compressa</i> .	Fish scales.
— <i>gibba</i> .	<i>Bos primigenius</i> ? (Hull Museum.)
— <i>reptans</i> .	<i>Cervus elaphus</i> . (Hull Museum.)
<i>Cypridopsis obesa</i> .	— <i>megaceros</i> . (Hull Museum.)
<i>Candonia detecta</i> .	<i>Elephas primigenius</i> ? (York Museum.)
— <i>albicans</i> .	<i>Equus</i> , sp.
— <i>lactea</i> .	<i>Felis spelæa</i> . (Hull Museum.)
— <i>candida</i> .	
<i>Limnicythere inopinata</i> .	
<i>Cytheridea lacustris</i> .	
<i>Anodonta anatina</i> .	

Two curious points are brought out by this list. Firstly, it shows that some of the extinct Pleistocene mammals, including *Felis spelæa* and perhaps *Elephas primigenius*, are true Post-glacial species, not confined in the North of England, as has been stated, to Inter-glacial beds. Unfortunately, though several teeth of the Mammoth have been found at Hornsea, it is not quite certain whether any of them really belong to this deposit, so it must still be left doubtful whether the species really lived in Holderness in Post-glacial times.

The second point is, that, notwithstanding careful search, the list of fresh-water Mollusca is extremely small, forming in this respect a marked contrast to the recent fauna of Hornsea Mere. That this is a real deficiency, and not due merely to imperfect search, I feel confident; for, for purposes of comparison, the recent Mollusca in the Mere were also collected, and in a short time more than thrice the number of species were obtained. No doubt several others, besides those recorded, may have lived in the old Mere, but the absence of all but these few species, and perhaps one or two others, at every locality where the lacustrine beds are seen in Holderness, tends strongly to show that they were not able to live in the district, or, more probably, had not yet had time to migrate into it. The recent Mollusca found in Hornsea Mere were the following, those also occurring fossil being marked with an asterisk. The list of living forms has purposely been confined to those found during a short search, but one or two others have been recorded.

* <i>Anodonta anatina</i> .	<i>Limnaea auricularia</i> .
* <i>Cyclas cornea</i> .	<i>Physa fontinalis</i> .
— <i>rivicola</i> .	† <i>Planorbis albus</i> .
<i>Pisidium casertanum</i> .	— <i>carnutus</i> .
— <i>henslowianum</i> .	— <i>complanatus</i> .
* — <i>pusillum</i> .	* — <i>contortus</i> .
<i>Bithynia Leachii</i> .	— <i>corneus</i> .
* — <i>tentaculata</i> .	* — <i>nautileus</i> .
<i>Limnaea glabra</i> (one dead shell).	— <i>nitidus</i> .
— <i>palustris</i> .	— <i>spirorbis</i> .
* — <i>preregra</i> .	— <i>vortex</i> .
† — <i>stagnalis</i> .	† <i>Valvata cristata</i> .
— <i>truncatula</i> .	* — <i>piscinalis</i> .

The three species marked (†), though not yet found fossil at Hornsea, occur in similar beds at other localities in Holderness, and Prof. Phillips also adds *Cyclas lacustris* from Skipsea, as well as *Limnaea stagnalis*. This, however, only raises the total number found fossil at all localities in Holderness to 12, while one locality, the modern Hornsea Mere, yields at least 26 living.

The cliff at Mappleton, over 40 feet high, is capped by another lacustrine deposit, which extends for half a mile north of the town. Where thickest the section is,—

	FEET.
Silt	3
Sand and Gravel	3
Laminated Peat, with small roots	3
Loamy Gravel	3
Boulder Clay	33

But the peat is very impersistent, and the whole of the beds are commonly replaced by gravel. No fossils were observed here, and the mammoth teeth picked up on the beach are probably derived from the glacial beds. Immediately south of this exposure is another smaller one, which, from the shape of the ground, probably belonged originally to the same mere.

The next Post-glacial deposit seen in the cliff is the valley Alluvium of the Lambwath Stream. The Old Dale evidently once extended much further east, over what is now sea, and the cutting back of the cliff has exposed a section which belongs to a valley draining westward. In the deepest part there is one foot of laminated shaly peat, which, according to Professor Phillips, has produced abundance of hazel-nuts, covered by eight feet of alluvial loam.

Three miles further south there is a similar bed in the dale east of Grimston Park, but it has been so much disturbed in making the old fishponds (the present cliff happens to cut through the middle of them) that the exact character of the deposits is not recognisable.

At Sand le Meer the coast line cuts across a valley draining inland, but the bottom of the valley is so low that, were it not for the sea bank, high spring tides might break through and reach the Humber. On the foreshore opposite this valley there is good evidence of a subsidence of the land, for the bottom of the old valley cuts to low-water mark; proving that the land must once have been considerably higher, or there would not be sufficient scour to erode the channel or to keep it clear. A small stream like this would need a fall of several feet in the mile to prevent its channel being blocked up. The deposits seen on the foreshore consist of peat and peaty loam full of tree stumps and roots, the stumps being seen in place below half-tide level. The fossils observed were,—

<i>Carex</i> , sp.	<i>Prunus padus</i> .
<i>Juncus</i> , sp.	<i>Anodonta anatina</i> .
<i>Potamogeton</i> , sp.	<i>Cyclas cornea</i> .
<i>Alnus glutinosa</i> .	<i>Pisidium pusillum</i> .
<i>Corylus avellana</i> .	<i>Valvata cristata</i> .
<i>Quercus robur</i> .	— <i>piscinalis</i> .
<i>Salix</i> , sp.	

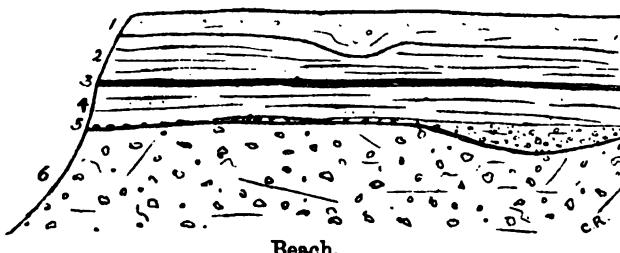
To this list Professor Phillips adds bones of oxen and antlers of stag.

Half a mile south of Sand le Meer two small patches of *Cyclas* Clay are seen in the cliff, but they are of no special interest.

Withernsea Mere is now only represented by a patch of swampy ground and a small pond; Owtthorn Mere has entirely disappeared. But the small alluvial flats still left seem to be the last relics of a mere of considerable size. The peaty lacustrine clay on the foreshore rapidly widens seaward, forming what is locally known as "Noah's Wood," which has yielded hazel nuts, fresh-water mussels, and antlers of stag.

Two miles south of Withernsea, and not far from Holmpton, Nevill's Drain flows into the sea, and for about 300 or 400 yards the cliff is very low, seldom more than 10 feet above high water. This low portion is covered by alluvial deposits in some respects unlike most of those already described. The section (Fig. 10) was seen in a projecting point near the northern end of the basin.

FIG. 10.—Alluvium in the Cliff north of Holmpton (seen in a projecting point). Scale 15 feet to 1 inch.



	FEET.
1. Soil	2
2. Loamy Alluvium	3
3. Laminated peaty bed with <i>Betula nana</i>	0½
4. Fresh-water loam with <i>Perca fluviatilis</i> , <i>Planorbis</i> , <i>Limnaea peregra</i> , <i>Cyclas cornea</i> , <i>Pisidium</i>	3
5. Gravelly soil, very irregular	0½
6. Boulder Clay	—

The first thing that strikes one in this section is, that we have here a bed with fresh-water shells, just like that described at so many localities, and *above* this is a peaty bed with the arctic birch, *Betula nana*. Unfortunately no plants are yet known in the lowest bed at Holmpton, and the shells belong to species too widely distributed to throw any light on the question of climate. The relative age of this bed, with arctic plants and the submerged forests, will be discussed after the rest of the sections have been described. Professor Phillips examined the same deposit in 1826, but the section he saw was so different from the one now visible, that his account may be worth quoting, especially as the coast must then have been many yards further east.*

Brown soil.

Bluish bed of argillaceous marl.

Shaly clay, changing upwards to white clay-marl.

Shaly bed of clay.

Blue and brown clay marl.

Black marl, with plant roots.

Grey marl, with *Cyclades* and *Paludina* [*Bithynia*].

Diluvial clay.

Unfortunately one cannot be certain whether his bed of "black marl" is the same as the one from which the arctic birch has recently been obtained; no measurements being given, it is impossible to say whether the lacustrine deposits thickened seaward.

A mile further south the Alluvium of Out Newton Dyke shows a somewhat similar section. The old channel must be silted up nearly 20 feet, and the lower part of the hollow is hidden by the beach. Gravel lines the channel and rises to the surface on each side, but in the centre we also find,—

	FEET.
Loam with peaty base	4
Cyclas Marl	5
Gravel, to beach	—

* *Op. cit.*, p. 71.

The base of the Loam was carefully searched for leaves; but though so like, both in lithological character and position, to the bed yielding *Betula nana* at Holmpton, nothing could be found in it; however, it is worth further examination, as the section changes very rapidly.

Towards Easington, east of the Mill, there is another alluvial flat showing three feet of Loam with a peaty base, but no fossils are preserved.

South of Easington there are no old lacustrine beds, but only *Scrobicularia* Clays at the present sea-level. These, though now cut into by the denudation of the coast, really belong to the Humber Warp, and will be again mentioned when that deposit is described.

Crossing the Humber we find one more of these old shell marls in Cleethorpes Cliff. Mr. Penning describes the section thus:—

“ The deposit in the centre of the cliff coincides nearly with an old channel running from the land to the sea, in which occurs the following succession of beds, varying in thickness, but fairly constant throughout:—

	FEET.
Sandy wash	3 or 4
Sand, yellow at top, grey below, with lines of carbonaceous matter	2 or 3
Brown stratified Loam, with an occasional bivalve shell having both valves united	up to 3
Bluish loamy clay	1
Grey sandy Loam or Marl, full of shells and plant remains, also beds of peat or lignite	up to 2
Sand (in places only)	1
Boulder Clay	1

“ The channel is about 300 feet in width, and its depth perhaps 15 feet at the deepest part.”

The shelly marl contains *Limnaea peregra*, *Planorbis albus*, *P. nautilus*, *Valvata piscinalis*, *Cyclas cornea*, and *Pisidium pusillum*; but no determinable plants and no bones were observed.

South of Cleethorpes, Warp and Buried Forests, like those of the Humber, are occasionally seen on the foreshore, but the old cliff of Boulder Clay having trended inland no lacustrine deposits are exposed.

Of the old meres for which Holderness was once so famous the only relic is often the name *Mere* attached to some farm or field, or even to a hill. Most of the irregular patches of Alluvium, of which so many are scattered over the country, are the beds of ancient meres; but in many cases they may have been either silted up in prehistoric times, or the name has since been lost. Of these dried up and now nameless meres numbers have been mapped, but a glance at the cliff section shows that many of the smaller ones may have been entirely overlooked inland; the want of sections, the perfect drainage, and the irregularity of their beds

rendering it difficult to distinguish them. A list of the old meres of which the names are recorded on the Ordnance Map is given below, but probably a local historian could trace back in ancient records the names of many now forgotten. For others traditional names might still be found, or their former existence may be recorded in the curiously slow changing names of separate fields.

Commencing at Bridlington, the deposit seen in the cliff is apparently only portion of the bed of a large irregular mere extending for a mile up the Gipsey Race and southward to Bessingby, but the name of this mere seems now lost. At Burton Agnes there is a wide spread of alluvial clay extending to Harpham: different parts of this are called "Moor" and "Carr," but the name "Mere" seems confined to the mill-pond known as Burton Mere. Near Little Kelk the Burnt Mill Beck flows through a flat called Duck Muttons: whether this name is connected with the old Mere is uncertain, but it is very suggestive. Along the course of the River Hull the alluvial flats do not seem often to have been occupied, within the historic period, by actual lakes: the names Carr and Moor are often met with, but not Mere. That meres did exist at one time is, however, shown by the occurrence of a sheet of shell-marl at Driffield.

Around Barmston and Ulrome meres were very numerous, but often the flats are too small to be engraved on the one-inch map. Though Soumers seems the only name connecting these flats with old meres, the discovery of pile dwellings at Ulrome shows that others certainly existed in the Celtic period, though their names have since been lost.* Between Hutton and Cranswick, Heddlemere Closes seems to preserve the name of an old mere; in this instance, however, the position of the mere itself cannot be fixed. Between Beeford and Catwick the former existence of two meres is recorded in Stephenson's Mere Drain and Clubley's Mere. At Skipsea there is White Marr. Near Brandsburton we find Swanmere End; and at Walton, Swan Mere. Eelmere Hill near Mapleton is directly above an old mere, but a mile and a half away there is also Eelmere Well. Near Great Colden there is Breamers, near Flinton, Braemere, and at Beeford Braemar Drain. Cross Mere Hill near Aldbrough, Midmeredales near Cottingham, Bowmere Hill, Turmar Farm, Gills Mere, and Bowmer Hill, all mark the sites of varnished lakes, but at Row Mere there is still a small reedy swamp. South of the Humber the names of others are recorded in Langmeer Furze, Micklemeer Hill, and Riby Slings Meer.

Besides the places where the word *mere* is still preserved, *mire* and *moor* are so often used for silted-up lakes, that it is probable that since the drainage there has been a slight change in the vowels, and many of these names were originally also *mere*. The local name for a swampy alluvial flat bordering a stream is commonly *carr*. Other ancient inland meres may also be recorded in

* See also p. 112.

the termination *ea* or *ey*, often met with where there is now no water except perhaps a small ditch.

Turning next to the estuarine Warp and the accompanying "Submerged Forests" of the Humber and Lincolnshire shores, we find that the only sections of the older portion have been seen during the excavation of the docks at Hull and Grimsby. Fortunately most of the works have been very carefully watched by the engineers and other observers, whose accounts have been published. These notes are among the most valuable material for the geology of Holderness, recording, as they do, extensive sections which, from the nature of the case, will probably never again be laid bare. The occurrence of true land surfaces at so great a depth beneath the sea-level has so often been denied, that it will be necessary to give full details, in the observer's own words, of what has been seen at Hull. The notes are taken according to the date of publication, thus reserving for the last the still unfinished Alexandra Docks, which have been examined many times in the course of the Survey with special reference to this point. The evidence from borings is so unsatisfactory that it can only be accepted when it corroborates what is seen in a clear section, but a glance at the Appendix will show that borings made at many places and by many different well-sinkers prove a succession of peat and warp beds curiously like that seen in the docks.

Writing in 1866, Dr. Foster thus describes the beds exposed in the Albert Docks at Hull:—"In the cuttings at the east end, the upper stratum is silt, . . . and immediately under the silt the trunks, roots, and branches of oak trees, together with a peat soil of two feet in thickness, beneath that a strong clay soil, and under this (so far as is uncovered) an extensive bed of blue sand, containing the fresh-water *Lymnaea*, *Planorbis*, &c."

"At a depth of 40 feet below the level of the adjoining land, trees (chiefly oak) are found in all positions; those which are upright and still *in situ* having been broken off within three feet of the roots. One oak-tree, of noble dimensions, is perfectly straight, its trunk being 45 feet long, and in the thickest part measuring 12½ feet in circumference; it is tolerably sound, but blackened in colour. This tree lies nearly north and south, but others, which have also fallen, are to be met with in every direction."

"In a hole caused by the decay of a branch, was found a quantity of hazel-nuts, possibly the winter store of some provident squirrel; the shells, though black, were quite perfect."

"The undulating state of the original surface may be seen by the silt above being of a lighter colour than the lower stratum. It is evident, from the position of the roots, that the ground on the north or land side, on which the trees grew, has been higher

* "On the Discovery of Ancient Trees below the surface of the Land at the Western Dock now being constructed at Hull." - Rep. Brit. Assoc. for 1866, *Trans. of Sections*, p. 52.

than the south or river side. . . . The trees . . . would require at least 300 years to attain the dimensions given."

According to Messrs. Wood and Rome* these docks "showed the Hessle Clay irregularly denuded and overlain by a bed of silt upwards of 20 feet thick, at the bottom of which were the remains of a forest growing upon, and with the stools in places rooted into, the Hessle Clay. This deep accumulation of silt abounded to the very bottom (where the shells rested on the forest) with the ordinary estuarine mollusca of the Humber,—*Scrobicularia piperata*, *Tellina solidula*, *Cardium edule*, *Littorina littorea*, &c. In part this forest-bed was also underlain by the silt, showing an oscillation of level during its growth At Hull the dock-borings showed this forest to be now from 20 to 37 feet below high-water mark of ordinary spring tides."

After the completion of the works Mr. J. C. Hawkshaw read a paper, unfortunately only published in abstract, giving fuller particulars of the sections exposed.† From this abstract the following account of the peat bed is taken:—"The Albert Dock extends for 4,000 feet along the Humber foreshore, and all the excavations were carried to a depth of at least eight feet, and in some instances of 27 feet, below the level of low water."

"Before the commencement of the excavations the Hessle Clay, peat, and overlying silt were met with in succession on the foreshore, the level of the top of the peat bed at the west end of the area being about three feet above the level of low water, and its thickness from three to four feet. Eastward the bed followed the undulations of the clay without much variation in general level for half a mile, when it began to dip, attaining a depth of 12 feet below low-water level at the lock entrance, and then rising again. From this depression of the peat-bed, and the appearance of the overlying silts, the author thought it probable that this had been an old channel of the river Hull. . . ."

"The peat rested directly on the Hessle Clay, into which roots penetrated to a distance of five or six feet, generally following the direction of vertical joints. . . ."

"At its highest level, at the west end of the dock, the peat consisted almost entirely of vegetable matters, including large accumulations of moss, leaves, and masses of brushwood, layers of oak-leaves with acorns, hazel-nuts, and fir-cones. Numerous remains of Coleoptera, chiefly wing-cases, were found. Trunks of oak trees, some of them 60 feet long, were scattered through the peat, and had evidently fallen where they grew; and, from the characters presented by most of them, it would appear that they had grown close together. In this part of the bed, at the level of low-water, and beneath a thick layer of moss, the remains of a fire were found. The author suggested that, from the small extent occupied by the remains of this fire, it was probably the

* *Op. cit.*, p. 157.

† "Notes on the Peat and Underlying Beds observed in the Construction of the Albert Dock, Hull."—*Quart. Journ. Geol. Soc.*, vol. xxvii. p. 237.

result of human agency, as, if it had originated by lightning or by the friction of dry branches, it could hardly have been confined to so small an area."

"With regard to changes of level, whilst in other places an upward movement has been indicated,* the area examined seems to furnish evidence only of depression. Thus the surface of the peat in the supposed old channel of the river Hull is 12 feet below the level of low water, whilst the bed of the present river at South Bridge is only 6 feet below that level. The depression of the forest converted the land on which it grew into a marsh, where soft vegetable matter accumulated rapidly and soon covered up the fallen trees, the soundness of the timber indicating no long exposure to the weather. As the land continued to subside, the marsh was invaded by the waters of a tidal estuary, in which the Mollusca lived whose shells occur in the grey clay overlying the peat, and even in the peat itself. Of these the following forms occur:—*Scrobicularia piperata*, *Cardium edule*, *Tellina solidula*, *Hydrobia*, sp., and *Bullina obtusa*;—all, except the last, in great abundance."

Turning now to the new Alexandra Docks, which are about two miles lower down the Humber, we find very similar sections, showing an old land surface at the same level, or perhaps slightly lower. In May 1884 the following section was measured, but since the water was shut out and the Dock drained, the warp has subsided considerably. The top of the section is now probably below the level of mean tide, though originally slightly higher. The lowest point reached at this spot is 52 feet below the coping:—

	FEET.
Clayey Warp	about 15
Warp sand, increasing towards the shore	5 to 0
Clayey Gravel with <i>Littorina</i>	1
Traces of the "Submerged Forest," consisting of a peaty seam with occasional tree stumps. This bed is here much eroded by the overlying Gravel, but the underlying Boulder Clay is often full of small roots	—
Reddish-purple chalky and stony Boulder Clay, much weathered in the upper part, but where the bed is thick the base is very like the older Boulder Clay. Blue joints occur throughout, though principally in the higher portion. Much Chalk and flint, Carboniferous Limestone, Coal Measure? Sandstone, Greenstone, Quartz Porphyry, &c. &c.	about 6
Fine chalky bedded Sand, without fossils	about 6
Dark purple very chalky Boulder Clay, unweathered	4+
	32

Another part of the Docks gave:—

	FEET.
Warp (silty sand)	18
Lignite and peat	2
Gravel	—

Probably Boulder Clay would be found immediately beneath.

* See above, p. 79.

A year previously many tree stumps had been seen on about the same level at another point; but so much water was coming in, that they could not be properly examined to ascertain whether they were actually rooted in the clay. The stumps subsequently seen were fewer in number, but had certainly grown where they are now found; most of them were small, but the navvies stated that now and then large trees occur. All the stumps observed appeared to be oak.

The overlying warp contains abundance of shells, the common Humber species, *Scrobicularia plana*, *Tellina balthica* (thin-shelled and small), *Cardium edule* (stunted), *Hydrobia ulvae*, and *Bulla obtusa* being scattered throughout, though other forms are rare. A boat was also found in the warp, and a bronze dagger. Warp, however, is so rapidly deposited that the depth at which such articles occur is no evidence of their antiquity. In the buried Forest itself no trace of the contemporaneous existence of man appears to have been noticed in these excavations; and the remains of a fire, probably caused by human agency, is still the only fact pointing in that direction.

Similar beds were seen in Grimsby Docks, but the notes available are less full. Mr. E. H. Clark observes* that "The subsoil consists, generally, of a top layer of soft, blue silty clay or deposit, averaging 24 feet in thickness. Under this is a layer of peat and leaves, averaging 2 feet 6 inches; then a stratum of sand and gravel; below which is stiff brown clay, averaging 30 feet. Underneath is a layer of green sand, mixed with water, averaging 2 feet; and below this is chalk rock, which is generally reached, in the neighbourhood of Great Grimsby, at depths varying from 80 to 100 feet below Trinity h. w. mark."

Messrs. Wood and Rome state that† "the borings at Grimsby Docks disclosed the forest-bed at still greater depths than at Hull, varying from 35 to 52 feet below high water of ordinary spring tides. . . . In some parts there were two forest surfaces, divided by a bed of leafy clay from 5 to 15 feet thick." Borings are always unsatisfactory in such cases, and it seems very doubtful whether the bed at 52 feet was really a land surface.

In the excavations an old channel was found, cutting deep into the Boulder Clay, and causing great difficulty with the foundations. Like the similar channel in the Albert Dock at Hull it was filled, not with peat, but with mixed warp and drift wood, which in a boring could scarcely be distinguished from a true forest-bed. Only one land-surface appears to have been observed in the actual excavations.

Notwithstanding the extent of the Docks and the number of borings made on the Humber and Lincolnshire Carrs, only one old submerged land surface has been found. This may vary in level, but is nearly always at or close to the base of the Warp. Occasionally on the Humber foreshore a land surface is seen

* *Proc. Inst. Civ. Eng.*, vol. xxiv. p. 38.

† *Op. cit.*, p. 157.

near low-water mark ; but, allowing for settling of the clay, and for the small roots having penetrated beneath the water level, there is no reason to think that this would show a greater submergence than 4 or 5 feet. A submergence to this extent may have been caused by a local alteration in the tides, and there seems to be evidence that such a change has taken place within the Historic, or at least Neolithic Period ; but this will be again alluded to in Chap. IX. The thick bed of Warp above the old land surface appears to point, as already observed, to a continuous and fairly rapid subsidence of the old forest ; a subsidence so rapid as to allow no time for peat again to form until the surface had sunk nearly to its present level, and till the accumulation of Warp had again raised the bottom above mean tides.

Post-glacial Natural History of Holderness.

At present very little is known about the natural history and climate of this district between the deposition of the last Boulder Clay and the Historic Period. It is evident, however, that there must have been a great deal of migration to adapt the animals and plants to constantly varying conditions. Though there is not yet such unmistakable evidence as we could wish, various indications point to the conclusion that the passing away of the Glacial Epoch was by no means accompanied by a steady amelioration of climate ; there appear to have been minor oscillations of temperature which did not produce actual glaciation in these lowlands.

Of such oscillations the proof will be found in the decidedly mild climate shown by the fauna and flora of the period of elevation described in the early part of this Chapter. We find the oak flourishing abundantly as the common tree, associated with other trees of wider range, such as the hazel, alder, bird-cherry, and willow. Among the higher animals the presence of man is perhaps indicated by the traces of a fire discovered in the lower buried forest at Hull Docks. The mammoth has also been recorded from several localities, though the evidence of the exact horizon from which the teeth and tusks were obtained is perhaps not so clear as it might be. The lion has been found at Hornsea, associated with the Irish elk, horse, and red-deer. From a considerable depth in the warp at Grimsby timber-ponds Mr. Cordeaux obtained a horn-core of the gigantic ox (*Bos primigenius*).

Altogether this is an assemblage not only showing a mild climate, but corresponding closely with that found in the Valley Deposits of the South of England.

The bed which has yielded the Arctic birch at Bridlington and Holmpton would naturally be considered of earlier date, and nearer to the Glacial Period, were it not that the whole of the stratigraphical evidence seems to show that it is much more modern. Though at present only this one Arctic species is known, yet it is so characteristic a northern form, that it seems sufficient evidence of a colder climate. Fossil, *Betula nana* is only found associated

with high northern plants; recent, it only occurs in northern Britain as a high alpine form.

In Holderness the evidence of superposition of the bed with *Betula nana*, unfortunately, is not clear. The structure of the country, however, is such that we can only account for its mode of occurrence if it forms the base of the recent alluvial and lacustrine deposits which fill hollows in the older beds.

Evidence of this reversion to a colder climate after the comparative mildness which seems to indicate that glacial conditions have passed away, is not confined to Holderness. In the Fenland the arctic birch is also found immediately beneath the recent peat, and in Denmark a large and characteristic Arctic flora has been discovered in a similar position. As this peat could not well grow till the land had sunk to about its present level, it seems that the period of elevation must here also have been of earlier date.

Little is yet known of the changes which occurred in Britain while the Glacial Epoch was passing away. Special attention is therefore drawn to deposits of that date in Holderness, for it may turn out that this latest oscillation of climate was connected with the final disappearance of many of the Pleistocene mammals, and perhaps also of Palæolithic man. Unfortunately there are very few workers in this field, for English geologists as a rule consider that such recent deposits scarcely belong to their province, and it is almost entirely to the hasty visits of foreign botanists and geologists that we owe our knowledge of the presence of Arctic plants in Britain.

The fauna of the Neolithic and Bronze Periods in Holderness cannot yet be separated from the Recent, except at Ulrome. There have been found the Celtic short-horn, red-deer, sheep, horse, wild boar, wolf, and perhaps otter. In the old silted-up channels cut through in the recent drainage works at Grimsby, similar remains occurred, including the horse, Celtic short-horn, deer, and goat.

CHAPTER IX,

CHANGES NOW IN PROGRESS.

Loss of Land.

From Bridlington southward, there being nothing harder than Boulder Clay to oppose the advance of the sea, the cliffs waste more rapidly than those of almost any other part of England. Much has been written on this loss of land in Holderness, but it is not at all easy to obtain measurements extending over a sufficient length of time to yield a trustworthy average of the annual amount. Old maps are seldom very accurate; in fact, none earlier than the Ordnance Maps are of much use for our purpose. The Doomsday Book, which at first sight ought to be a valuable aid, is rendered less useful by the impossibility of fixing the exact sites, and distances from the cliff, of places since destroyed, and also by the omission in the record of any note of the waste lands which were included in the area now lost.

Under these circumstances it has not been found possible to add much to the measurements and estimates given by previous writers, and the following details are largely taken from the papers of Smeaton,* Dr. J. P. Bell,† Mr. G. G. Kemp,‡ Mr. W. Shelford,§ the Rev. F. O. Morris,|| and Mr. R. Pickwell.¶ The loss of land since the earliest Ordnance Map was made is also given, but the time that has elapsed is too short for the measurement to be accepted as a fair test of the average rate of denudation. Tuke's map of Holderness gives measurements from certain fixed points taken in 1786. It is the earliest trustworthy authority.

Between Flamborough Head and Sewerby the rate of denudation is comparatively slow, for the foreshore and base of the cliff is composed of hard Chalk, and the sea is evidently laying bare the old buried Chalk cliff, but is not cutting much into the solid rock. Apparently the loss is considerably under a foot annually; probably not over half a foot. The piers and defensive works at Bridlington Quay, by retaining the beach, affect the coast as far north as Sewerby, and the rate of loss since 1871 has only averaged about half a yard annually between those points. The coast line at Bridlington projects fully 280 yards beyond that south of the town, and if no groynes had been made great part of this 280 yards would now be sea.

Immediately south of Bridlington Harbour the rate of loss during recent times suddenly increases, and Mr. Pickwell gives it

* "Narrative of the Building of the Eddystone Lighthouse," &c. Fol. London. 1st. edit. 1791, 2nd edit. 1813.

† *Report Brit. Assoc.* for 1853, p. 81.

‡ *Report Brit. Assoc.* for 1853, *Trans. of Sections*, p. 53.

§ *Proc. Inst. Civ. Eng.*, vol. xxviii. p. 472.

|| "Sea versus Land on the East Coast of Yorkshire."—*Leisure Hour*, 1877, pp. 620-623.

¶ "The Encroachments of the Sea from Spurn Point to Flambro' Head," &c.—*Proc. Inst. Civ. Eng.* 1878, vol. li. pp. 191-212.

as 2 yards per annum from 1805 to 1852, increasing to 3·5 yards per annum from 1852 to 1872. Since 1872 it has averaged, according to Mr. Lamplugh, 5 yards per annum. This shows that measurements of the loss during a short period may give an average very different from the true one,—which for this portion of the coast is very difficult to determine. The erection of groynes, though preserving the cliff to the north of the town, has evidently increased the rate of denudation to the south.

At Hilderthorpe Mr. Pickwell gives the rate of loss between 1805 and 1852 at 2·1 yards per annum, but near the site of the old village of Hartburn it is given as only 80 yards in 120 years. At the south end of the parish of Barmston from 1756 to 1876 the average appears to have been 1·1 yards per annum. Near Barmston Drain the loss in 120 years was 126 yards. At Ulrome the average is about 1·2 yards annually; at Skipsea, just under 2 yards annually during 111 years; at Skirlington, 1·9 yards during 107 years. Near Atwick the loss during 107 years has averaged 2 yards annually.

Southward it increases, Mr. Pickwell giving an average of 2·5 yards for 67 years at the northern end of Cliff Lane, Hornsea, and 1·9 yards near the Marine Hotel, where the coast is partly protected by groynes. At Hornsea the rate appears to have been extremely irregular; for, if the old inquisition held at Hornsea and quoted by Mr. Pickwell can be believed, the loss for the previous 63 years was 4 yards annually; but the expression "twelve score yards" does not look like exact measurement; and the statement made by one of the witnesses that "there doth usually every year waste the breadth of 40 feet, which is more than heretofore," seems scarcely trustworthy. No doubt the destruction of the pier would cause a great increase in the rate of denudation for a short time, and it might reach the large annual amounts here mentioned. The increase, however, could only make up for the former protection of that part of the coast, the projecting portion being merely cut back till it attained the general line of the cliffs on each side. The *average* rate of denudation for a longer period would remain almost unaffected. As far as can be made out, the loss at Hornsea has averaged a little more than 2 yards annually, but Mr. Bell places it nearly as high as 3 yards between 1786 and 1853.

At Hornsea Burton farmhouse the loss of land between 1845 and 1876 was 1·3 yards per annum, but between 1876 and 1882 it had increased to 5 yards annually. Probably the alteration was due to the more effective stoppage of the travelling of the beach at Hornsea since new groynes were made. Opposite the Brick-yard at Hornsea Burton the average rate of loss since 1845 has been 1·6 yards, and in 1882 the sea was only 10 yards from the cottage.

Southward the rate of denudation increases, Mr. Pickwell stating that the loss at Mappleton between 1786 and 1874 was 206 yards, or 2·3 yards per annum. Between 1852 (the date of the Ordnance Map) and 1882 it varied from 40 to 50 yards in different parts of the parish.

Great Colden is rapidly being destroyed, though between 1764 and 1833 the annual loss, according to Mr. Pickwell, was only 1·3 yards. Since 1852 it has averaged 1·7 yards, and the eastern corner of the old house in the moat now overhangs the edge of the cliff. Immediately north of Frank Hill, in a detached portion of Colden Parva parish, there has lately been a very great loss of land, no less than 115 yards having gone since the Ordnance Map was made: this gives an annual rate of 3·8 yards. Southward as far as Aldborough the loss during the same period has averaged about two yards.

In 1786 Aldborough Church was 2,044 yards from the cliff, in 1882 the distance was reduced to 1880 yards, yielding an average loss of about 1·7 yards per annum. The highest land being near the cliff, the rate of denudation south of Colden is likely to increase, for as time passes there will be a smaller mass of material for the sea to remove.

The loss of land at Ringbrough has been about 1·6 yards annually since 1833, but the rate varies much during different periods; it is apparently now increasing. Near Grimston Garth the loss has averaged only about 1·4 yards since 1833, but the cliff is over 70 feet high. According to Mr. Pickwell the loss opposite Hilston Church between 1777 and 1852 was at a still lower rate, being only 1·1 yards per annum. Since the Ordnance Map was made the rate has not altered.

From Tunstall southward the old Ordnance Survey dates from 1822, and the loss of land since that time has been so great that the new coast of 1881 has been engraved on the Map of the Geological Survey. Tunstall Church was 924 yards from the cliff in 1786, in 1881 the distance was reduced to 733 yards, giving an average annual loss since 1786 of 2 yards.

At the Coast Guard Station at Waxholme the loss between 1844 and 1852 was at the rate of 1·2 yards per annum: between 1852 and 1881 it increased to 1·4 yards, and the cliff was cut back till it reached the corner of the gardens at the station. The loss at the most northern farm in Waxholme between 1844 and 1852 is stated to have been 2·6 yards per annum; since 1852 it has only been, at the rate of 1 yard. A short distance further south it has averaged 1·3 yards during the last 30 years.

Since 1852 (when the 6-inch Ordnance Map was made) the bend in the high road leading from Waxholme to Owthorne has been cut away by the sea, stopping the communication, except through the farmyard adjoining. The rate of loss at this point has been 2 yards per annum since 1812.

Near Owthorne and Withernsea the groynes put up in 1870 have stopped denudation for a time, but between that date and 1786 the average rate appears to have been almost exactly 2 yards per annum. In this neighbourhood the rates seem to vary within very wide limits, and a longer period is needed to yield a satisfactory average. Even since 1822, the date of the old Ordnance Survey, the village of Owthorne with a church and twelve houses

has been entirely swept away, and Owthorne and Withernsea Meres have both disappeared.

South of the village of Withernsea there is a sudden and great increase in the breadth of the strip of land lost since 1852. For a mile and a half it is 100 yards wide, giving an annual rate of 3·3 yards. This is far above the rate for a longer period, and probably much of the extra loss is due to the erection of groynes at Withernsea in 1870-71. Further south, at Nevilles, the waste from 1794 to 1852 is given by Mr. Pickwell as 0·7 yard per annum; since 1852 it has been much greater, being 2·3 yards annually for a period of 30 years.

Holmpton Church is stated to have been 1,200 yards from the sea in 1786; in 1881 the distance was reduced to 1,042 yards, giving an annual loss of 1·6 yards. Much of this loss, however, appears to have happened in late years, the average since 1851 being 2·5 yards.

At Old Hive, between Holmpton and Out Newton, Mr. Pickwell gives the loss from 1802 and 1852 as 0·9 yard per annum, and from 1852 to 1876 as 3·5 yards, yielding a general average of 1·7 yards. Measured on the old Ordnance Map the loss is very much greater, having been 5·5 yards annually since 1822. It is difficult to reconcile these calculations; and as the Ordnance Map is not very accurate, the real rate is probably nearest that given by Mr. Pickwell, though probably rather greater.

The old ruined chapel at Out Newton in 1882 was about 40 yards from the edge of the cliff. Here also the rate of denudation has lately become much more rapid. Between 1771 and 1852 the loss was only 0·8 yard per annum, but since 1852 it has increased to 3 yards.

Owing to the exceptional height of the cliffs at Dimlington High Land, there is so large a mass of material to be removed that the loss is not very rapid, being at present under 2 yards per annum. Opposite Dimlington Farm there has been a marked increase in the rate of denudation during recent years. From 1771 to 1852 it was 1·8 yards per annum, since that time it has been 2·3 yards.

Easington Church in 1771 was 1,056 yards from the cliff; in 1882 the distance was reduced to 850 yards, giving an annual encroachment of the sea of 1·9 yards during 111 years.

The parish of Kilnsea is wasting more rapidly than any other part of Holderness, and the last house of the village has now been washed away. As lately as 1822 it contained a church and thirty houses; on the Ordnance Map of 1852 it has still six or seven houses and the foundations of a church seen at half tide; since that time the last house has been washed away. Between 1766 and 1833 Mr. Pickwell estimates the loss at 1·8 yards per annum, and between 1833 and 1876 at 5 yards; since 1876 the rate has decreased again to 3·3 yards. At Kilnsea, as in most of the rest of Holderness, there seems to be a tendency for the rate of denudation to increase, much less being lost annually in the first

half of the century than during the second. Perhaps a series of measurements taken during a longer time might prove this to be an accidental variation, not affecting the general average; but at many places it appears to be connected with the abstraction of shingle for road-making, &c. (See p. 105).

Inside the Humber the parish of Kilnsea is also suffering slightly, and for half a mile there is a low cliff of Boulder Clay facing westward. The lost town of Ravenspur was somewhere in this neighbourhood, probably rather further south.

Leaving for the present the changes which have taken place in the shifting bank of sand and shingle which forms Spurn Head, we again find a cliff of Boulder Clay at Cleethorpes, in Lincolnshire. This cliff only extends for half a mile, and is apparently wasting at nearly the same rate as the similar cliffs of Holderness. Judging from the present contour of the ground, the cliff has probably only come into existence within the last 200 or 300 years; this portion of the Lincolnshire coast before that time having been flanked, like all the rest, by a belt of salt marshes and sand dunes.

As already observed, the roll of the lost towns and parishes of Holderness, though interesting from an historical and archæological point of view, helps us little to fix the rate of denudation. The former site of even so important a place as Ravenspur (or Ravenser as it is often spelt) is very uncertain, and after much discussion the locality can only be fixed to the extent that the town lay on the Humber side of the point, not far from Kilnsea. Attempts have been made to measure the rate of denudation since 1080 by deducting from the areas of the parishes mentioned in Doomsday the portion now remaining. Then estimating the breadth of the lost portion as equal to the present cliff frontage, a calculation can be made of the width of the strip lost. Of course the result will not be correct for any particular instance, but from a number of examples a trustworthy general average might be obtained, as the errors in a large series would tend to counter-balance each other. Unfortunately, the series is much too small to be of any avail, and the results are vitiated by the impossibility of taking into account the parishes *entirely* destroyed, or the alterations of boundaries, since the Doomsday Book was made.

Of ordinary subaërial denudation there is very little now going on in the low lands of Holderness, for what is washed off the Boulder Clay is almost entirely deposited on the Alluvial flats, scarcely any of it reaching the sea. Probably if it were not for the extent of ploughed lands and roads, and of deep artificially cleared ditches which allow a more rapid flow of water, the subaërial denudation of Holderness might be entirely left out of account.

The removal of lime in solution must, however, be a considerable item, and one little affected by cultivation of the land. No analyses have been made of the water flowing over the Boulder Clay, or given out by the Glacial Sands; but the enormous extent

to which calcareous shells and Chalk have been dissolved shows that the bulk removed must be very considerable. Springs from the Glacial Gravels always contain much mineral matter in solution, principally lime and iron, and it is a curious fact that the water from a Gravel is usually much harder than that from the Chalk.

To sum up, denudation in Holderness is at present mainly confined to the coast line, and, as far as can be judged, the annual loss averages about $2\frac{1}{4}$ yards. This, along a coast of about 40 miles, equals 34 acres annually. The rate during the last 30 years, however, is considerably greater, probably nearly 3 yards, or 45 acres annually; but this increase appears to be principally due to the abstraction of shingle and to the erection of groynes. If marine denudation usually proceeds at this rate, the loss since the occupation of the country by the Romans must amount to a strip between two and three miles broad: 4000 years since Bridlington Bay had no existence.

Travelling of the Beach.

From an inquiry into the rate of denudation the transition is natural to an inquiry into the subsequent dispersal and distribution of the material. Taking the average height of the cliffs at about 53 feet, measured from the level of low water, and adding to this 30 feet, or 5 fathoms, as the approximate depth of scour, there is removed annually from the coast of Holderness a mass of material amounting to about 118,300,000 cubic feet and weighing 5,900,000 tons.

Of this mass the greater part consists of Boulder Clay full of scattered boulders of varying size and hardness. The larger boulders, that is, those over a foot in diameter, usually consist of hard tough rocks, such as Gneiss and Basalt. These are too large to be rolled and broken up on a shelving sandy beach like that of Holderness, but they gradually find their way, by the undercutting of the Boulder Clay on which they rest, to lower and lower levels, till they have sunk to a depth of several fathoms without moving far horizontally. In this mode are formed the "Stone Banks," which are so common at short distances from the present shore, and probably also many of the banks of boulders and large bones which occur at various points in the North Sea. Of late years a large number of these boulders have been immediately removed for building and road-making, but many still work their way below the water-level, and prevent the sea from scouring to so great a depth as it would otherwise do.

Stones under a foot in diameter, and sand, go to make the beach of Holderness, which is continually moving southward. Probably there is a rapid change of material, for few of the stones are perfectly rounded, and there seems to be a great tendency for them to follow the larger boulders and work their way below

tide-marks. There is thus a strange deficiency of beach at many points where no artificial abstraction, and no exceptional southward travelling, can interfere.

Altogether there is much less beach in Holderness than one would expect, taking into account the large number of stones annually washed out of the Boulder Clay. What beach there is consists principally of shifting banks of sand, which, unless fixed by groynes, are of little use in protecting the coast during storms.

The deficiency of beach is generally ascribed to the abstraction of shingle for building and other purposes, and the amount thus removed from the southern half of Holderness has been placed as high as 60,000 tons per annum during the years immediately preceding the Board of Trade restriction. But, accepting this high figure, it can scarcely represent more than a tenth of the amount annually produced, and the rest of the deficiency must be due to natural causes. No doubt the removal of so large a mass from just the points where it was most needed caused an enormous amount of mischief, but the mere stoppage of the abstraction is not likely to make much difference in the ordinary width of the beach, except opposite the larger villages and at Spurn Head.

Commencing at the northern end of the district, the southward travelling of the beach is very marked near Bridlington, where the defensive works have not only protected the town and caused a slight accumulation of beach to the north, but have also led to a much more rapid scour south of the town, where the beach is deficient. About a mile and a half south of the Quay the beach again widens and is more stony, the influence of the groynes having probably died away. From Wisthorpe to Skipsea there is generally a slope of sandy beach about 40 yards wide, and a wet tidal flat of sand varying from 200 to 300 yards. Between Skipsea and Hornsea there is usually a marked deficiency of beach, the Boulder Clay being commonly exposed in large patches between tide marks.

At Hornsea the protection of groynes is again felt; the beach is in places over 100 yards wide, and is backed by a line of Sand Dunes. Owing, however, to the former removal of a large number of stones for building purposes and road metal, the beach has been left very sandy, and liable to be rapidly washed away should the groynes be destroyed. South of Hornsea the effect of the groynes is now being felt in the deficiency of beach, and consequent more rapid wasting of the cliff; but the present groynes being very modern, the cutting back is not yet sufficient to endanger the defences, as it does at Bridlington.

From Hornsea to Withernsea there is a marked deficiency of beach, and as none is now taken from this part of the coast the absence is probably due to the set of the waves and currents, which draw the beach outwards instead of driving it along the coast. Much of the foreshore between tide marks is bare Boulder Clay.

Judging by the rate of denudation since the 6-inch Ordnance Map was made (1852-3), the protective influence of the groynes at Withernsea is felt for about two miles northward, but the extra deficiency of beach seems also to extend fully two miles south of the town. The defences were put up in 1870, and have been effective till now, though the want of beach on the lower side of the southernmost groyne allows the sea to get behind it, and needs constant attention.

From Withernsea southward the beach becomes more and more deficient, much of the cliff being washed by nearly every high tide. At Easington and Kilnsea this absence of beach is particularly conspicuous, for there are certainly in most places fewer stones in the beach than the Boulder Clay would yield in a single year. Not only is the upper part of the beach wanting, but there is also scarcely any sand, the whole foreshore being a gentle slope of bare Boulder Clay, over which a few boulders roll and help to cut up the clay. The absence of beach may be partly accounted for by artificial abstraction; but as the abstraction has been stopped by the Board of Trade for the whole district from Spurn Head to Hornsea since 1869, it must be largely due to natural causes. The outward movement of the beach, which the undertow during on-shore gales tends greatly to assist, is probably the principal reason of the deficiency.

At Kilnsea Warren the Boulder Clay finally disappears, and for three miles a narrow bank of sand and shingle divides the Humber from the North Sea. This bank, the southern end of which is Spurn Head, is a continuation of the beach which has been gradually travelling southward along the coast of Holderness. So rapid and so important are its changes, both from a geological and economical point of view, that their history must be given as fully as possible, especially as the probable future changes are a constant source of anxiety, and may cause great loss if not properly directed.

Spurn Head.

Previous to the 17th Century an allusion in Camden's *Britannia* (published in 1586) is the only clue we have to the ancient form of Spurn Head. But possibly his statement that Kilnsea was then at the extreme point of Spurn Head is not to be taken literally; it may only mean that the village was at the end of the solid land, the shifting bank of sand beyond being left out of account.

Less than 40 years after Camden wrote, Callis incidentally mentions that "of late years parcel of the Spurnhead in Yorkshire, which before did adhere to the continent, was torn therefrom by the sea, and is now in the nature of an island."* It is, however, impossible to say whether this refers to the shifting sand-banks, or to an overflow of the sea through the alluvial flats which

* *Lectures on Sewers* in 1622, 2nd edit., 4to, 1685, p. 44.

cross from sea to sea near Kilnsea. Callis is merely treating the question from a legal point of view, and discussing the rights of the Crown and private owners in new islands. Mr. Shelford suggests that on a former occasion also Spurn had been an island, and it was on this ground that the inhabitants of Grimsby in 1289 claimed certain privileges there. This seems probable, for since records have been kept the Head has been alternately an island and a peninsula several times.

During the 17th century changes must have taken place very fast, for "in the year 1676 a patent was granted by King Charles II. to Justinian Angell, of London, merchant, enabling him to continue, renew, and maintain certain lights that he had erected upon the Spurn Point. Which lights were erected at the request of the masters of ships using the Northern Trade; who, in their petition to his Majesty, represented that a very broad long sand, about six or seven months before, had been discovered to have been thrown up near the mouth of the river Humber."*

The first survey of Spurn Head was that made by Captain Greenville Collins, Hydrographer to the King, in 1684. In this map the Head is shown with a broad oval portion, on which are Angell's Lights, connected with the main land by a narrow belt,—much as it is at the present day, though shorter. No trace of the island Callis mentioned is shown, unless it be represented by the Den, which then lay S.W. of the Point, and not behind it, as it does now, or by the broad head which had subsequently become attached to the main land.

By 1766 the Point had increased so much in length that application had to be made to Parliament for power to erect new lights, those established by Mr. Angell having been rendered useless through the southward extension of the Point. The "Broad Long Sand" complained of in the above quoted petition had become dry land at high water, and continued to increase.

Smeaton was therefore consulted, and advised the erection of two lighthouses, "to be in a N.W. and S.E. direction; and to be 300 yards asunder. The great Lighthouse to be placed on Spurn Point, at a distance from high-water mark (at common spring tides) of 90 yards, in a N.E. and S.W. line; and 150 yards in a N.W. line, within the Spurn."† The breadth of the land from sea to sea in a N.W. and S.E. line was then 566 yards. As the erection of these Lighthouses would take a considerable time, two temporary lights were erected 250 yards asunder, and 23 yards S.W. of the ground marked out for the permanent Lighthouses, and were lighted in 1767.

"Between 1766 and 1771 the sea encroached so much that the place fixed for the Low Light, at 116 yards within high-water

* Quoted by Smeaton, "Narrative of the building of the Eddystone Lighthouse." Appendix on Lighthouses at Spurn, fol. 1791.

† *Op. cit.*, and "Reports," vol. i. pp. 152-278.

mark, according to the line of direction, was now on the very high-water mark itself." The position had, therefore, to be altered 80 yards more inland, or to the N.W. In 1772 the High Light was begun 60 yards more to the N.W. than originally intended, the distance between the houses being thus 280 yards.

Unfortunately, until the buildings had been actually commenced Smeaton had never been to Spurn otherwise than by water, and was unaware that the movement of Spurn Head westward was not merely temporary, but must keep pace with the denudation of the coast to the northward. In 1776 a great storm washed away the circular wall round the Low Light, and laid bare the piles on which the main building was founded. Seeing that nothing could be a permanent defence to this building, except what would defend it as an island, Smeaton advised that it should be repaired at a moderate expense, and a temporary light placed 30 yards more inland, ready for immediate use should the Light-house be destroyed.

In 1786 Smeaton's survey of the Spurn showed that the High Light was 1,840 yards south of Angell's Light, and was 480 yards from high-water mark at the end of the point.

The earliest Admiralty Chart after 1684 is from the Survey of Captain Hewett, and is dated 1823. It shows numerous changes in the submerged and half tide banks, a further southward extension of the point, and there is a note that the southern part of the Neck overflows at high spring tides. Thus the point is again an island.

"In 1849 a large breach occurred in the Spurn Neck, north of the Lighthouses, and in 1850 Captain Vetch held an Admiralty inquiry on the spot. He reported in favour of strengthening the point on its seaward face, by means of groynes placed at right angles to its length, for the purpose of intercepting the shingle in its passage southward, and on the Humber side by the further reclamation of the accretions east of Sunk Island."*

By 1863 the sea had reached the High Light itself; and the Low Light, after being rebuilt further westward three times, had been removed to the Humber side of the Head. In the same year some of the groynes recommended by Captain Vetch were erected; till now these have been sufficient to protect Smeaton's High Lighthouse from further damage.

The Admiralty Chart now in use is dated 1875-7. It shows the Head much narrower and longer, and the Neck broader, than formerly; the gap through which the sea broke has been again filled up. Since 1864 there has been a gain of land to the eastward, due to the prohibition by the Board of Trade of the removal of shingle, and to the erection of groynes. Mr Pickwell states that the eastward gain of land along the entire length of the neck between 1869-70 and 1875 varied from 30 to 80 yards, or

* Shelford: "On the Outfall of the River Humber."—*Proc. Inst. Civ. Eng.*, vol. xxviii. p. 479.

an average of 6 yards per annum. The westward movement had also been arrested, and between 1864 and September 1875 there had been a further southward extension of the point of 60 yards, or 5·4 yards per annum.*

From Mr. Shelford's and Mr. Pickwell's calculations we therefore obtain the following table of the known southward extensions of Spurn Point :—

1676 to 1766	-	1,800† yards, or 20 yards per annum.
1766 to 1771	-	280 „ 56 „
1771 to 1786	-	150 „ 10 „
1786 to 1851	-	300 „ 4·6 „
1851 to 1864	-	113 „ 8·7 „
1864 to 1875	-	60 „ 5·4 „

This gives an average rate for 200 years of 13·5 yards per annum, and at that rate the whole spit would be formed in 400 years. If, however, we accept the more rapid increase during the 17th century, and carry it back for about 100 years, till the date when Camden wrote, the result is that the long spit of sand which now forms Spurn Point had then no existence, but commenced to form a few years later, and has gone on increasing ever since.

Thus we can trace the growth of this long bank of sand and shingle from its commencement till it has reached its present length of about 3 miles. But this naturally leads to the inquiry, if the bank only commenced forming about 300 years ago, what became of the southward travelling beach before that date?

This difficulty has apparently been overlooked, though it is a real one, and led to a close search for the missing shingle while the Geological Survey was in progress. On examining the Lincolnshire coast opposite Spurn Head the mode of disposal of the shingle produced by the denudation of Holderness is discovered. Though there is only one small cliff south of the Humber, at Cleethorpes, and that has probably existed less than 300 years, yet there is a very large mass of shingle beach near Donna Nook, separated from the Boulder Clay by an Alluvial flat six miles wide. This shingle cannot have been produced by the erosion of the Lincolnshire coast, which is mostly clean Warp and Clay without stones, but apparently must have crossed the Humber from Spurn.

At present there is no evidence, and little probability, that anything coarser than Sand can cross the Humber mouth. But the process seems to be an intermittent one. A beach begins to form at Spurn, as it did in Camden's time, the point lengthens more and more, the neck becomes thin, the sea breaks through, and a bank of shingle becomes detached. Then the north channel becomes wider and wider, as the sea and wind drive the island

* *Proc. Inst. Civ. Eng.*, vol. xxviii. p. 192.

† This is only an approximate measurement, as the exact distance from Angell's Lights to the end of the Point in 1676 is not known.

southward, like any other part of the beach, till at last the bank is transferred from Yorkshire to Lincolnshire, and the process recommences. This seems the only way to account for the disappearance of the shingle from Holderness, and for the occurrence of an old wide shingle beach near Donna Nook.

Within the last 300 years we have seen all the earlier stages of this movement, but the enormous mass of shingle artificially removed during the present century has rendered the movement slower, and now the erection of groynes prevents for a time the re-formation and widening of the gap which the sea made in 1849. Since 1869 the Board of Trade has prohibited the removal of shingle between Spurn and Hornsea; but it remains to be seen exactly what effect this prohibition will have. Sir John Coode estimated the amount removed from the south-east part of Holderness at 60,000 tons per annum; and if the greater part of this is added to Spurn, it must overflow the groynes, and cause so great an elongation of the Point as to seriously interfere with the entrance to the Humber. As it is, Spurn Point is driving the stream southward, and causing it to cut more and more into the Lincolnshire coast,—though this may not be an unmixed evil if it should ultimately produce deeper water near Grimsby.

The stoppage of the natural westward movement of the whole of Spurn Head by the works on its seaward face has been severely criticised by Mr. Shelford, who thinks that it will lead to the Head being outflanked. He contended that "the works on the seaward face of Spurn Point were on wrong principles, and the longer they were continued the more complete would be the ultimate destruction of the present Spurn Point."* Without going so far as this, it may be pointed out that before long it will be absolutely necessary to erect groynes as far north as Kilnsea, or the Point will become detached. The influence of the present groynes is only felt for a very short distance northward, and they do not seem to affect in the slightest degree the rate of the denudation of the narrow neck of Boulder Clay north of the Warren.

This question of the continuation of the groynes northward is a very complicated one, for there are many different interests to be considered. If it were only for the protection of the land from the heavy yearly loss, Mr. Pickwell has clearly shown that the interest on the outlay for works would much exceed the value of the land washed away, and works ought only to be undertaken if they would also improve the seaports of the Humber. Before discussing this question it will be well to trace the finer material removed during the denudation of the Holderness cliffs, and to attempt to ascertain where it is deposited.

Warp and Silt.

The amount of material annually removed from the Holderness coast by the sea may be estimated at about 6,000,000

* "On the Outfall of the River Humber."—*Proc. Inst. Civ. Eng.*, vol. xxviii. p. 516.

tons, of which the greater part, probably 5,000,000 tons, is sand and mud. The coarser sand largely goes to form the sand-banks which block the Humber and North Sea, or the sand-dunes which cover Spurn Head and protect the Lincolnshire coast. But the fine mud and silt is carried to much greater distances. Not only are the Humber and Lincolnshire flats raised by it, but the enormous quantity of warp which is annually deposited in the Wash can have no other source; for there are no cliffs to yield it in Lincolnshire, and the mud of the Norfolk cliffs appears to travel principally to the southward.

In the Humber, as in the Wash, the warp brought down by the rivers may be left out of account, for the bulk of it is probably deposited on their alluvial flats long before it reaches the estuary. More mud seems to be carried into the rivers by the tide than comes down them.

The amount of silt held in suspension in the Humber is very great, but is not yet accurately known, for the few observations made refer only to the surface water. Probably much more silt and sand, especially coarse sand, is carried along near the bottom than ever rises to the surface. Sea-water being heavier than brackish water, there is also a tendency for the flood tide to run for a time underneath the ebb. Thus the time during which silt is carried upwards is longer than it appears; and mud and sand are stirred up and carried along the bottom while the less charged surface water is flowing in the opposite direction.

Mr. Sollit has published a series of observations on the constituents of the silt.* But, unfortunately, he has omitted to state whether the samples were taken near the shore, or well out in the stream; also what was the rate of the current when the sample was taken, or whether the water was much agitated by wind.

Notwithstanding this, Mr. Sollit's account is very valuable, as showing how highly the water of the Humber is charged with silt, and how large a part of this silt is fine sand, and not clay. He stated that "in a gallon of water taken from the Humber when the water was agitated by the tide either running up or down, there were from 315 to 320 grs. of this fine deposit, and that it was so exceedingly fine as not all to have settled at the end of ten hours from the taking of the water from the river."

The following samples were obtained at different points:—

BROUGH.			
Sand, moderately fine			77
Alumina			6
Carbonate of lime			6
Carbonate of magnesia			1
Soluble salts			2
Oxide of iron			2
Organic matter			6
			<hr/> 100

* "On the Chemical Constituents of the Humber Deposits."—*Rep. Brit. Assoc. for 1853, Trans. Sects.*, p. 49.

HESSLE.

Sand, very fine	-	-	-	-	75
Alumina	-	-	-	-	7
Carbonate of lime	-	-	-	-	6
Carbonate of magnesia	-	-	-	-	2
Soluble salts	-	-	-	-	3
Oxide of iron	-	-	-	-	2
Organic matter	-	-	-	-	5
					100

HULL.

Sand, very fine	-	-	-	-	71
Alumina	-	-	-	-	7
Carbonate of lime	-	-	-	-	6
Carbonate of magnesia	-	-	-	-	2
Soluble salts	-	-	-	-	5
Oxide of iron	-	-	-	-	2
Organic matter	-	-	-	-	7
					100

NEW HOLLAND.

Sand, fine	-	-	-	-	69
Alumina	-	-	-	-	13
Carbonate of lime	-	-	-	-	5
Carbonate of magnesia	-	-	-	-	1
Soluble salts	-	-	-	-	4
Oxide of iron	-	-	-	-	2
Organic matter	-	-	-	-	6
					100

PAULL.

Sand	-	-	-	-	82
Alumina	-	-	-	-	4
Carbonate of lime	-	-	-	-	3
Carbonate of magnesia	-	-	-	-	trace
Soluble salts	-	-	-	-	5
Oxide of iron	-	-	-	-	1
Organic matter	-	-	-	-	5
					100

GRIMSBY.

Sand, fine	-	-	-	-	76
Alumina	-	-	-	-	10
Carbonate of lime	-	-	-	-	2
Soluble salts	-	-	-	-	5
Oxide of iron	-	-	-	-	3
Organic matter	-	-	-	-	4
					100

"This sample contained no carbonate of magnesia. Mud taken three or four miles below Grimsby is nearly all sand, and of a much coarser kind. In some places it is a mixture of the coarse sand with a little of the finer deposit of the Humber, which is found at all places higher up the river."

The silt is so fine that it is kept in constant motion by the tides, and can only settle in sheltered places. It, therefore, does not

greatly affect the navigable channels of the Humber, though they are much blocked by banks of coarser sand, which travels along the bottom.

Though the sand-banks and channels of the Humber are constantly shifting, there are no sufficiently exact records to prove any great diminution in the capacity of the estuary. There has certainly been a narrowing of its breadth at high-water, but Mr. Shelford's diagrams apparently show that there has also been a gain in depth of the channel, at any rate between 1828 and 1852. This question of the changes in the depth of the navigable channels will be found fully dealt with in Mr. Shelford's paper, and in the discussion which followed the reading.*

The silt and mud, though perhaps not causing any diminution of the water-way for ships, are largely deposited between tide marks. Thus tract after tract gradually rises to near the level of high-water, and is then protected by embankments and added to the area of the cultivated land. The process takes place principally in shoal water, where the tidal currents are never strong. Till the level of half tide is passed the deposition of the sediment is probably slow, and can only take place at high-tide when the water is still. Afterwards the growth of salt-marsh plants binds the mud, and by straining out and entangling the particles of sediment, lengthens the time during which mud can be deposited. The marsh thus rapidly rises to within a foot or two of ordinary high-water mark, and the growth gradually changes from samphire to sea-lavender, seablite, and sea purslane, then to thin wiry grass, and afterwards to better grass, fit for pasture, though liable to be flooded by the sea.

Mr. Oldham observes that when the surface is thus covered with vegetation, the land may at once be embanked; but if it is enclosed from the tide before it obtains a green carpet, it may be twenty years before it is of much value for agriculture, for scarcely anything will grow upon it. After it has reached the high-water level of ordinary spring tides, the growth and transformation of the salt marsh into good land must be very slow, unless artificially assisted; and the land gained is always liable to be flooded by an exceptionally high tide, or to be washed away or cut up by channels formed by the sea.

The rise and embankment of Sunk Island is so characteristic of the process, and the history of its changes is so well known, that it will be described fully. The other reclaimed areas in the Humber show merely the repetition of the process on a smaller scale, and will be alluded to afterwards. As Mr. Oldham, who, as engineer to the Commissioners of Woods and Forests, has had special opportunities of studying the question, has published a full history of the gradual growth and embankment of the island, the following account will be mainly taken from his papers.†

* *Proc. Inst. Civ. Eng.*, vol. xxviii. pp. 472-516.

† *Proc. Inst. Civ. Eng.*, vol. xxi. pp. 454-492; and *Report Brit. Assoc. for 1853*, pp. 36-45.

The earliest account we have of Sunk Island is probably in the time of Charles I., when it contained about 9 acres, was a mile and a half from the Yorkshire coast, and had a navigable channel between it and the mainland, through which ships of considerable burden could pass. Immediately after this period the Island rapidly increased, and in 1668 it was first granted on lease to Anthony Gilby, Esq., for a term of 31 years, at a rent of 5*l.* per annum, when it was described as containing 3,500 acres of drowned ground, only seven acres of which was then embanked. A stipulation was inserted in the lease for the embankment by the lessee of 100 acres or more within the first 10 years of the term, but by 1675 the lessee had only succeeded in embanking about 20 acres.

The earliest map showing Sunk Island is that made by Captain Greenville Collins, hydrographer to the King, in 1684. It shows a sand-bank about 8 miles long, dry at low tide, called Sunk Sand. Towards the western end of this bank is Sunk Island, about three miles long, with an embanked portion half-a-mile across. The long channel separating Sunk Island from Holderness is about half-a-mile across at low water, but over a mile when the tide is high.

In 1712 it is stated that the Island produces "all sorts of grain, but especially barley and oats, which come to much greater perfection than in any other part of Yorkshire besides, or in the neighbouring counties. Besides these there grows a good deal of woad."*

A survey of Sunk Island made in the year 1744 showed that 1,500 acres had been embanked, and that the estate was divided out into farms. Some time before the falling in of the lease in 1802 another survey was made by order of the Surveyor-General of Crown Lands, and it appeared that the quantity of land then embanked was only 1,561 acres, no addition having been made since the year 1744. But the Surveyor reported that above 2,700 acres of new ground were fit for embankment.

In 1833 the land in actual cultivation contained no less than 5,929 acres of excellent quality, then divided into 15 farms, besides some small holdings. Under Mr. Oldham's direction a further embankment of 700 acres was made in 1850, and there is now altogether of land within the banks, secured from the tides, and also available grass beyond the banks, little less than 700 acres, and a prospect of still further increase.

Besides the formation of Sunk Island, there have been other minor gains in the Humber, especially at Cherry Cobb Sand, Patrington, Ottringham, and Welwick. The area of these cannot be exactly ascertained, but Mr. Oldham considers that the total increase, including Sunk Island, from Paull to the Spurn, was about 10,000 acres between the years 1684 and 1850. On the south side

* Leland's Itinerary, Hearne's edit., vol. ix. p. 194.

of the Humber there have also been marked changes, but no very great permanent gain of land. Read's Island, which at one time seemed about to form a valuable addition to the Crown property, has since decreased considerably, and at South Ferriby a low cliff is being cut.

Altogether the gain of land in the Humber during the last 200 years may be taken at about 15 square miles. But this 15 square miles includes only the areas which have been raised to the embanking level (about 2 feet below high-water spring tides) during this period. The old tidal flats taken in must have been very large, but it is difficult to find any records of the dates of their embankment. Mr. Shelford estimates that the total area of the reclaimed lands below high-water spring tides in the estuary of the Humber is about 290 square miles. All of this has probably been embanked since the time of the Romans, though much of it may have been raised above the embanking level long before that period.

Unfortunately we have no means of estimating the exact depth from which Sunk Island and other recent reclamations have been raised during the last 200 years. It is therefore impossible to tell what proportion of the 5,000,000 tons of silt and sand annually removed from the coast of Holderness is deposited in the Humber. But, disregarding for the moment the cubic contents, the 15 square miles gained since 1684, when Captain Grenville Collins' chart was made, may be accepted as a fair equivalent for the 11 square miles lost. And if to this be added only half of the 45 square miles gained in the Fenland during the same period, we have 37 miles gained to only 11 lost.

Taking into account the height of the cliffs in Holderness, a gain more than three times the loss is not so absurd as it at first appears. The total thickness of the deposits denuded is more than four times, probably as much as seven times, the average height to which the shallow beds of these two inlets have to be raised before they can be embanked. If the depth of scour off Holderness were merely *equal* to the average depth of water to be filled in the Humber and Wash (it is really much greater), this alone ought to yield an alluvial flat about the same size as the area denuded. But the height of the cliff and depth of scour in Holderness are together about 80 feet, while there is an enormous area in both the Humber and Wash which less than 15 feet more silt would raise to the embanking level.

Thus, in the future, as in the past, each square yard washed away in Holderness may be expected to yield at least 3 square yards of silt lands in the Humber and Wash, and these lands will be more than equal in value to those lost.

It may be objected to this calculation, that the silt of the Wash really comes in the main from the Norfolk coast, though half of it is credited to Yorkshire. As it is impossible to prove that it comes from the North, though the set of the tides strongly points to that conclusion, the whole of the loss and gain between Flambro' and the end of the Norfolk Cliffs will be added together.

Measured in this way, the loss in the past 200 years has been about 16 square miles, 3 miles of which was poor sandy land. The total gain in the same period was 60 square miles, all of which is exceptionally rich.

In these calculations round numbers have been purposely used, as several of the data cannot be accurately estimated, and a seeming exactness may mislead as to the real value of the figures. They are only brought forward as a rough estimate showing the general tendency of the changes now in progress. As such they may probably be accepted as near enough for ordinary purposes.

If this estimate is even approximately correct, it entirely alters our view of the serious loss to the country which is commonly supposed to be inseparable from the wearing away of our sea-coasts. It shows that instead of a loss there is a large gain, which would be entirely stopped if the coast were protected by groynes. Not only this, but the efficient protection of the coast would cost a great deal more than the expense of embanking the new lands.

Therefore, for the advantage of the country at large, it seems best to let well alone. Though individual landowners suffer, and are anxious for Government to go to the expense of protecting the coasts of Holderness and Norfolk, yet others gain at a larger rate. It may be worth while also to point out that new islands being Crown property, the public revenue is increased if the natural changes are allowed to take their course, while groynes would only protect private property.

Of course the protection of Spurn is quite a different question, but I cannot help thinking that to embank the 10,000 acres inside the Point, as Mr. Oldham advised, and to allow the Point to retire westward, would be not only the cheapest but the best way of preserving the Humber. The tidal water on these very shoal flats cannot have much influence on the scour, and the embankment would protect the Point on the west side.*

Apparent Changes of the Sea-level.

In the last Chapter mention was made of the occurrence of traces of a fire in a Submerged Forest at Hull beneath the level of low water, but this is the only indication in the district of either subsidence or elevation of the land since the occupation of the country by man. There is no evidence of any permanent change of the sea-level within the Historic or Neolithic Periods in Holderness, though a very small change may possibly have occurred. Dugdale mentions that in 1357 the King was "informed that the tides in the Rivers of Humber and Hull did then flow higher by four foot than they had wont to do; by reason whereof the common Road-way leading from the Town of Anlaby to Kingston-upon-Hull, as also the lands and Pastures lying betwixt both those places, and the

* See also Shelford, *op. cit.*, p. 515.

Town of Hesell, were overflowed and consumed."* This increase in the rise of the tide at Hull may have been connected with changes at Spurn Head, though we have no records going back so far.† Probably the removal of the bar which seems occasionally to form across the mouth of the Humber would sufficiently account for the increased range, for there is no reason to believe that the level of mean tide has changed. The same increased range of the tides would account for the occurrence of dead trees in the Carrs at a level 3 or 4 feet lower than they could now grow,—they need not necessarily be very ancient, neither do they show any subsidence of the ground.

On the Lincolnshire coast, near Tetney, Marsh Chapel, and Grainthorpe, there is an extensive Alluvial flat, from 6 to 9 feet above the present Marsh, which at first sight appears to prove a former higher level of the sea. However, the loam yields nothing but land, and a few fresh-water shells, and seems to be an ordinary fluviatile warp, not an estuarine silt like that of the present Marshes, which cut into it in every direction. The occurrence of fluviatile loam at this level is very difficult to account for, for it is separated from the Boulder Clay by two miles of lower Alluvium, and there is nothing to keep the water at a sufficiently high level to form it.

The origin of this high-level Alluvium is probably connected with the former northward extension of the Somercotes Beach and Sand Dunes till they touched the Boulder Clay near Cleethorpes. This obstruction to Tetney Haven and the other outlets would raise the water-level on the landward side of the Dunes, and allow fresh-water Alluvium to be deposited considerably above the sea-level. Afterwards the breaching of the Dunes by the sea would lower the water-level, and allow the old Alluvium to be cut up and destroyed, to be redeposited at a lower level. The whole process is probably connected with the transfer of beach from Spurn Point to the Lincolnshire coast.

That there has been no noticeable change of the level of the open sea for over 1800 years seems proved by the recent discovery by Mr. Boynton of a pile-dwelling at Ulrome, at about the ordinary marsh level. There is still some doubt as to the exact age of the dwelling, but the following account, taken from the *Standard* of Oct. 20, 1883, shows that it is almost certainly pre-historic.

"Ulrome Grange stands on the higher ground of the Boulder Clay, and the land juts out thence towards the 'stream dike' in a peninsula. Opposite this peninsula the Boulder Clay rises into an island, the elevation of the flat top of which is twenty-five feet above sea level. The distance between the Ulrome peninsula and the formerly water-surrounded ground—still called 'Goose Island'—was the ancient waterway between two contiguous lakes, and in this waterway the pre-historic lake-dwelling was erected. It was in the deepening of the artificial drainage to which we

* Dugdale, "History of Imbanking and Drayning," 2nd edit., fol. 1772, p. 132.

† See above, p. 104.

referred, that the turning out of bone tools and fragments of piles suggested the search by which the discovery of the lake-dwelling arose, and from which also the ancient lacustrine conditions of the district have been subsequently in a considerable degree made out. In this waterway a platform was first commenced by placing trees and brushwood on the natural ground of the lake bottom. These trees consisted of oak, two kinds of willow, birch, alder, ash,* and hazel. The trunks were some of large size, fifteen or eighteen inches in diameter, and as many feet in length, and had all been cut down, but none were squared. These timbers were roughly placed to form a nearly rectilinear platform. They were placed on the north side, which was down the course of the stream, between two straight rows of blunt-pointed stakes, and this timber dam was still further supported from being washed away by several diagonal piles, placed to lean towards the mass as buttresses. On the south side, facing the motion of the stream, there is a single line of stakes to secure the timbers. The timbers were not indiscriminately thrown in, but are placed alternately longitudinally parallel with the length of the side, with shorter timbers put transversely, forming a rough interlacing. The outer sides of the platform are of timber, and the infilling of the interior space was mainly done with brushwood and branches, the surface having been levelled with bark and strewn with sand. The size of the platform is about fifty feet by seventy-five feet, the length being from east to west, or across the flow of the water between the peninsula and the island. The platform would seem to have been connected by plank bridges at the south-east and south-west corners with the neighbouring land. One of the platform's timbers at the surface of the floor at the south-east corner has had its upper surface axed flat, probably for this purpose. The surface of the platform at the present time is three feet below the surface level of the surrounding land; but it is ten feet above the bottom of the lake.

"The platform, as it is shown by the excavations, is of two ages. In the lowest construction rude bone, flint, and stone implements and articles are found, amongst them hammers and picks made from the antlers of red deer, and also fragments of very coarse dark pottery with white grains, such as constitutes the materials of the oldest kinds of British pottery. This original work was at a subsequent period raised and extended by the addition of further timbers and more brushwood. In this upper and newer portion a bronze spear-head has been found; and the piles which have been driven into the platform to support or form the superstructures erected upon it are long-pointed, and show plainly right-handed cuts by a metal axe used vertically. The original platform may be thus clearly assigned to the earliest part of the Neolithic Stone Age, and the later platform to the Bronze Age. The relics found in the older construction would give to it a greater antiquity than that of the crannoges, and it is as yet the first case

* The occurrence of the ash is very unusual, and needs verifying.

of a primitive lake-dwelling being explored in England, the only other instance of any traces of even a single English lake-dwelling being the relics obtained at Barton Mere near Bury St. Edmunds, in Suffolk, where some bronze spear-heads and other weapons were found in 1867 in and around piles and stones, with bones of animals. The implements found in the lower platform at Ulrome are most interesting, and some are of previously unknown type. Of the latter are some ten or a dozen made of the upper joint-ends of the fore-leg bones of large oxen, seemingly of *Bos urus*, which are broken off about the middle of their length and the broken portion split aslant, forming large gouge-like implements, which are each perforated by a hole about an inch in diameter drilled through between the flat sides. It has been suggested that these implements attached to long handles might have been used as hoes for tilling the ground. Of the simple relics of animals discovered in the older pile-dwelling are head and horns of *Bos longifrons*, head of horse, bones and jaws of red deer, teeth and jaw-bones of wolves or large dog, bones of sheep, tusks of wild boar, a small skull, apparently of otter, and two bones of a large bird, probably goose. There have been found also some pieces of charred wood. Of the flint articles there are some rectangular masses about an inch and a half thick, roughly squared to about six inches by four inches, by innumerable small short chippings, many flake knives of various sizes, flint spoons, and a core from which small flakes had been riven, probably for pointing arrows. There have been also found a large, rounded oval, coarse-grained stone with a flat surface for grinding (about fifteen inches by eight inches in dimensions), and a number of cup-stones and hammer-stones."

" It is very important to remark on the precision and care taken by Mr. Boynton in the exploration, and which in regard to these bone and flint relics leaves it quite clear that none of them have been found nearer than six or seven feet from the surface, and that the bottom of the lake itself was covered by four to six feet of peat formed before the second platform was raised upon the previous structure.* The evidence of the extreme antiquity of this older lake-dwelling is thus made clear; and certainly there is no doubtfulness or confusion by the commingling of relics, as too often takes place in ordinary grubblings and mound diggings. The whole course of the stream dike from Skipssea to a mile or more northward of its junction with the 'Old Howe' was undoubtedly in the pre-historic period a chain of lakes, and there have now been found indications of five other lake-dwellings upon their former sites."†

From this account of the pile-dwellings at Ulrome we may gather that, though there has apparently been no subsidence since

* This does not necessarily show any subsidence of the land, but merely compression of the peat and brush-wood as they decayed.

† See also J. W. Davis, "Geological Excursion to Holderness."—*Proc. Geol. Soc. Yorkshire*, n.s., vol. viii. pp. 271-275.

the Neolithic Period, there has been a considerable amount of silting up, and all the meres and sluggish streams are rapidly changing to Alluvial flats. Such Alluvial flats often entirely surround islands or hills of Boulder Clay, which at first sight seem to have been islands in the old estuary. This, however, can scarcely have been the case with most of them, for the soft clay and sand would not remain while an intricate tidal channel was being cut all round.

The Alluvial flats merely mark the site of silted-up valleys, the bottoms of which were gradually more and more raised and widened as the land sank. At last the warp even passed over some of the lower ridges which separated the different streams, and turned what were merely the higher parts of an undulating country into islands divided from the main land by swamps. Borings or deep ditches on the warp often prove that some of the lower elevations were entirely buried; for, at long distances from the main mass, we sometimes find bosses of Boulder Clay much nearer the surface than we should expect. If a fresh subsidence were now to take place, more of the islands would entirely disappear; but other hills would be surrounded by the tide, and afterwards by warp, so that the general character of the country would be unchanged.

CHAPTER X.

ECONOMIC GEOLOGY.

SOILS.

Holderness being essentially an agricultural country, the nature of the soils and their connection with the geology is of the greatest importance. Agriculturally the district is usually divided into Moor and Carr, Warp, Clay, or Wold lands; Gravel soils forming only subordinate patches.

The term Moor or Carr is applied to a fresh-water swampy Alluvial flat, liable to be often flooded unless artificially drained. Most of the Carrs are now well drained, but the available fall of the streams is so slight, that in many places portions can still be seen in very nearly their original state. These remnants of the old Carr lands are sometimes merely reedy swamps, in which are abundance of wild fowl. Generally, however, where not interfered with, they are covered with clumps of alders and willows. Some of the beds of the old Meres, being below the ordinary level of the Alluvium, are very difficult to drain effectually.

The peaty places which mark the sites of many of the old Meres of Holderness are commonly called Moors. They are generally soft and wet, and full of fallen trees or rotting stumps. As the soil is not good, and is not likely to repay any great outlay for marling and effective drainage, they are usually either

left as rough pasture or planted for cover. Along the course of the Hull River and its tributaries, numerous patches of peaty land may be seen, but elsewhere they are small and unimportant. There is a good deal of Peat at the upper end of Hornsea Mere, and on it is a thick growth of poplars, though the original wood has nearly all disappeared. Along the course of Laceby Beck the peaty Carrs are perhaps more nearly in their original state than anywhere else in the district.

The area of the ancient Moor lands of Holderness cannot now be estimated, for the Peat is usually very thin, and rapidly wastes away and disappears under the plough. Large areas in the neighbourhood of the Humber have also been raised by artificial warping, till their character is entirely altered. Probably when first drained great part of the Carrs were covered with thin Peat.

The ordinary Carrs, or drained Alluvial flats, are very extensive, averaging about two miles wide along the course of the River Hull. They form an Alluvial soil, apparently of less value than the tidal Warp, but much better than the Peat. Like the Moors they are now generally used as pasture, though till lately great part has been under the plough. The artificial drainage of these Carrs is generally of ancient date, and as complete as possible without pumping. It has been almost entirely effected by deepening and straightening the channels, clearing their outfalls, and keeping out the tidal water. Still many of the Carrs are flooded for a considerable time during the winter.

The tidal Warp of the Humber forms some of the richest land in Holderness; but, as with the Carrs, at present there is a tendency to lay it down for pasture, where agreements do not prevent this course. One great difficulty in using it for pasture is the badness of the water-supply, which prevents cattle fattening. The water is nearly everywhere brackish and very unpalatable. North of the Humber, unless fresh water can be brought from the higher lands, it is difficult to see how this can be remedied, for the water from wells is also brackish, and in Sunk Island filtered rain-water from the house-tops is used for drinking purposes. South of the Humber an abundant supply of good water is obtained from wells bored to the Chalk, and usually there is one or more of these on every Marsh farm.

Large quantities of mustard are grown on the warp lands, especially on the strong warp; on the light warp potatoes are largely grown. The rotation on a farm at Hedon was:—

1, fallow; 2, mustard for seed; 3, wheat; 4, seeds (one stone of white dutch, half stone of red clover); 5, wheat; 6, oats and beans.

On a farm near Keyingham it was:—

1, fallow; 2, half mustard, half wheat, all sown with seeds; 3, seeds mown and fed (18 lbs. of seed, half white and half red clover); 4, wheat; 5, oats.*

* Coleman, Report to the Agricultural Interests Commission.

The natural fertility of this soil must be very great, for Mr. Oldham observes that soon after the land is embanked a spontaneous growth of white clover makes its appearance. The reason for always mixing white Dutch with the red clover on the strong lands of Holderness is that red alone is found by experience to tend to produce "yellows" in sheep.

Boulder Clay covers more than half the area of the low lands of Holderness. It forms a stiff rich marly soil, very good for corn and most other crops. Though wheat is the main crop, barley is extensively grown, and seems to be gradually replacing wheat, which no longer pays. Like the rest of Holderness the Boulder Clay land is nearly always in large fields, cropped on the four-course system. Anything beyond the ordinary corn, seed, or root crops is now very seldom seen, and one of the first points to strike a stranger passing through the country is the almost entire absence of any of the unusual crops which vary the monotony in other parts of England. Of course the sharp east winds of spring prevent orchards or fruit from succeeding, and account largely for this disinclination to try anything fresh. Only one or two fields of flax were observed during the progress of the Survey, and they did not look well. Formerly flax was more extensively cultivated.

How valuable this land is, is well shown by the close-cut hedges, roads commonly no wider than necessary, and the almost entire absence of commons in Holderness. The soil has always been celebrated for its fertility, for as long ago as 1613 Drayton, in his song on the East Riding, speaks specially of the corn of Holderness.*

..... "then note upon my South, . . .
How all along the Shore, to mighty Humber's mouth,
Rich *Holderness* I have, excelling for her graine,
By whose much plentie I not onely doe maintaine
My selfe in good estate, but Shires farre off that lye,
Up *Humber* that to *Hull*, come every day to buy,
To me beholding are "

Where anything edible is discussed Michael Drayton seems to be a very trustworthy authority.

Though nominally most of the land of Holderness is cropped on the four-course system, the Report of the Agricultural Commission shows that a five- or six-course system is not uncommon. As examples of the rotation on strong Boulder Clay lands, Mr. Coleman mentions a farm at Hedon on the system of, 1, fallow or roots; 2, wheat or barley; 3, seeds grazed; 4, wheat; 5, oats or beans.

Another at Walton Abbey is, 1, fallow or rape eaten off by sheep in autumn; 2, wheat; 3, seeds grazed; 4, wheat; 5, beans.

A third at Skirlaugh gives, 1, fallow; 2, wheat; 3, seeds; 4, wheat; 5, oats; 6, beans; 7, wheat; 8, fallow.

* "Poly-olbion," fol. 1613, p. 147.

Nearly all the agreements specify a definite rotation to be followed, though, as long as the land is not impoverished, some variation is usually allowed. Laying down to grass would be more undertaken were it not contrary to agreements.

On lighter land at Walton Abbey, worth 30s. per acre in 1880, the rotation was, 1, turnips ; 2, oats or wheat ; 3, seeds ; 4, wheat ; 5, oats or barley.

At Shirlaugh the system was, 1, turnips ; 2, barley ; 3, seeds ; 4, wheat ; 5, oats.

Mr. Coleman considers that the proportion of grass to arable land in the upper part of Holderness varies from one third to one fourth. A larger proportion of grass might be laid down with advantage, though at present the change is progressing slowly. The insecurity of tenure, as well as the agreements, hold many back from making improvements and laying out capital. But, besides these difficulties, the dryness of the climate is unfavourable to pasture.

The Gravel lands cover only small areas, forming isolated patches dotted all over the country. Of true Gravel soil there is very little, though there is some decidedly gravelly land at Rise, Hornsea, and Laceby, and around Kelsey Hill. Most of the area coloured as Gravel on the Map has a loamy soil a foot or two deep over it; thus, instead of being poor land, it has a well-drained rather light soil, very good for barley and oats. On the more gravelly parts potatoes are much grown.

The occurrence of loamy soils over Gravel would not strike one as anything peculiar, if it were confined to low-lying patches, dominated by higher Clay lands from which the loam might wash. But when isolated Sand and Gravel hills are covered with a loamy soil, like the hill on which Hornsea Water-works stand, the mode of origin of the soil is not nearly so clear, for it must either have existed before the denudation of the valleys, or have travelled uphill. In these cases, as in the Wold soils mentioned below, the transport of dust by dry winds has probably been the agency which has improved the Gravel soil and rendered it fit for cultivation.

While the Survey was in progress it was constantly found that the soil was no test of what lay two feet underneath. Not only did loamy soils overlie tracts which wells and open pits proved to be sand, but nearly every isolated hill of Boulder Clay had a patch of lighter soil on the top of it. Some of these Boulder Clay hills were originally mapped as sand, but after the examination of several of them which had been cut through by the cliff, or by deep ditches, it was found that nearly all were Boulder Clay, with only a thin capping of lighter soil.

The origin of these loamy caps is probably in each case the same. A dry wind has blown away many of the finer particles from the exposed portion of the Boulder Clay hills. These have been scattered far and wide, turning the soil in sheltered parts into a stiffer and more impervious Clay than a simple Boulder Clay soil would be, and adding enough Clay to the Sand to turn

it into a fertile loam. No doubt rain-wash has had something to do with the formation of the mixed soils, but it cannot account for the travelling of the Clay up-hill.

Though this mixture has greatly improved the agricultural value of the land in Holderness, it has rendered it much more difficult to make a Geological map, and causes such a map to be less useful for agricultural purposes than it would otherwise be. An accurate map of the soils would now be almost impossible to make, for high farming also has so changed the character of much of the land as to quite alter its agricultural value.

Much of the eastern slope of the Wolds is covered with patches of Boulder Clay and Gravel. These form a well drained, light or variable, loamy soil, which extends over the Chalk far beyond the outliers of Drift. This soil is usually good and very easy to work.

Above 200 feet, which is generally the extreme limit to which any trace of Glacial Drift is found, the soil, instead of being derived from the Chalk, is a very sandy loam, composed principally of rounded grains of quartz with scattered loose flints. Naturally this soil is very poor, the large crops which it is made to yield being only the result of long continued marling and manuring. So poor is the original soil that at first it is difficult to believe that the sandy gorse-clad strips sometimes found by the edges of the Wold lanes are nothing but uncultivated portions of the fertile fields on either side. However, if a field is left unmanured for two or three years the artificial character of the soil is soon apparent. The succulent grasses die, or are driven out and replaced by tufts of rough wiry grass, while between the tufts grows a carpet of moss and lichen.

The natural Wold soil is so unlike that of the Downs of Sussex, though the Chalk is almost identical in chemical composition, that attention is soon drawn to the contrast. On the Wolds microscopic examination shows that it is essentially a sandy soil, and the sand is quartz, not flint. The soil of the Downs, on the contrary, is usually much more loamy, but also contains quartz instead of flint. This difference between the soils causes the Downs to be clothed with short sweet turf, while on the Wolds grow only gorse, wiry grass, and moss. The Downs, therefore, being good natural pasture, have in great part always been left as such; while the Wolds must either be cultivated and manured, or be nearly useless.

This is apparently the reason why so little of the Wolds, and so much of the Downs, is left uncultivated. Unfortunately, the necessity for giving up growing crops which no longer pay, may soon lead to the abandonment of much of the higher Wolds, and their reversion to the original state. It has often been pointed out that the conversion of the Wolds into arable lands was unwise, and that they would have been better as sheep farms. But the warning was not heeded while good seasons and the high price of corn rendered the breaking up of new land profitable. Now it is too late to change without great expense, for in many places the

thin soil has become so impoverished that it will not even produce the grass it yielded in its original state without much manuring. Ploughing has also tended to remove the soil from the slopes, where formerly the best grass grew, and on the high lands has often allowed the wind to remove much of the soil, leaving only the flints.

The bareness of the Wold and want of shelter is another great objection to its use as arable land. There is no natural wood, though within the present century large areas around Brocklesby and Limbor have been planted. Beeches thrive well, and other trees seem fairly successful, though here again the shallowness of the soil is a great drawback, and trees are very easily uprooted. Probably under present circumstances much of the exhausted Wold would pay better if planted than in any other way. More extensive planting would also break the force of the biting east winds, which now do so much harm and help to render the yield so uncertain.

The staple products of the Wolds are sheep and barley. The yield of barley per acre is commonly not large, but the exceptionally fine quality makes up for the deficiency, and causes it to fetch a high price even when the average for other sorts is low. In 1880 the rent of Wold farms was about 26s. to 36s. per acre, and the average about 30s. or 32s. per acre, but since then it has fallen considerably, and will probably fall still further.

Mr. Druce gives the rotation on a farm on the Lincolnshire Wolds as, 1, wheat; 2, turnips; 3, barley; 4, seeds; 5, turnips; 6, barley; 7, seeds or clover; 8, wheat.

On the northern part of the Yorkshire Wolds Mr. Coleman mentions that on Lord Londesborough's estates it has been found impossible to continue the original four-course system without interruption, as the land became "sick" of clover and turnips in quick succession. The rotation practised on the best farmed districts is now, 1, seeds; 2, wheat; 3, turnips; 4, oats; 5, peas; 6, turnips; 7, oats; 8, seeds. The average rent of these farms was from 20s to 25s. per acre.

The soil of the Wolds, though often less than 6 inches thick and immediately overlying the Chalk, is very slightly calcareous. It is, therefore, necessary periodically to marl the fields to prevent turnips from running to "fingers and toes." This marling, or rather chalking, is done by opening pits in the middle of the fields, and spreading the Chalk over the surface. The pits are very shallow, and when new ones are opened they are commonly made to continue those previously worked. By digging the Chalk in this way, only large shallow depressions are left, which can be immediately ploughed over.

The marling is completed in the autumn, so that the winter frosts may break up the lumps. But if no frost occur that season, the lumps become hardened, and may remain for many years unbroken.

The immediate effect of the chalking seems to be to impoverish the land, but afterwards it is greatly improved. Mere deep

ploughing, which would also commonly turn up Chalk, is worse than useless, apparently because the Chalk near the surface has already been hardened by the weather. Perhaps also the upper layers have lost some component which would go to fertilize the soil, were it not already dissolved out. But without analysis of both weathered and unweathered Chalk it is difficult to say whether the change is chemical or mechanical, or both.

The origin of the far-transported soils of the Wolds I have already attempted to explain.* In both the Wolds and Downs they seem to be produced by the agency of dry winds, which, sweeping across areas of clay and sand, have deposited a thin coat of dust over hill and dale, or have slowly driven before them the heavier grains of sand. Even at the present day, gales in the spring and winter, when the vegetation has died down, sweep clouds of sand up the Wold escarpment, so that there is now three or four feet of Blown Sand capping the high hill near Pelham's Pillar, above Caistor.

This Blown Sand has drifted into many of the Dales, and also goes to form the bulk of the six inches or foot of soil which covers the bare Chalk. The finer dust, which might have improved the soil, appears only to have lodged in the hollows, the winds being too strong for it to remain on the open Wold.

In treating, from a geological point of view, of the origin of soils, it may be well to draw attention to the necessity for entirely separating the question of the chemical and mechanical constituents of the soil from that of subsoil drainage. A Chalk subsoil, from the facility with which it absorbs and retains water, causes the thin overlying soil to be dry, but seldom parched. For instance, Chalk being near the surface over the Downs and Wolds, both districts have the same sort of dry subsoil. The similarity does not extend, however, to the soils themselves, though high farming now compels both districts to yield very similar crops.

As an instance of the converse of this, a sandy soil overlying a bed of clay may be chemically identical with a similar soil overlying sand. But the difference of the sub-soil drainage makes the two soils, for agricultural purposes, quite unlike, and no artificial drainage will entirely remove the greater wetness of the soil resting on clay. On low flat grounds, like those of Holderness, sand and gravel also tends to become waterlogged, and then produces a marsh vegetation very like that found on swampy flats of clay. Even Chalk occasionally becomes waterlogged and produces a similar vegetation.

BRICK-MAKING.

Except for building material and road metal, no pits are opened in Holderness, and nothing, save bricks and tiles, is sent beyond

* "Dust and Soils."—*Geol. Mag.*, dec. iii., vol. i. pp. 165-168.

the district. Next to agriculture, brick-making is the most important industry of Holderness at all connected with the Geology.

For local purposes brick-yards are opened almost anywhere in the Boulder Clay, with much the same result. Unless well washed, and most of the Chalk removed, this Clay makes very indifferent bricks.

Where the Boulder Clay contained originally little Chalk, or is of the Hessle type,—that is to say, is decalcified,—it is a good deal better, and is often used without washing. The whole of the deposit in this case is passed between rollers to crush the stones, only the larger ones being picked out. The bricks at these yards being made by machinery, the result is fairly good, though it is doubtful whether the crushing up of pyrites and pyritous shales with the other materials will allow the bricks to last long. Large yards on this system will be found at Hornsea, Grimsby, and Cleethorpes. At all of them tiles and drain pipes are made as well as bricks.

Clean laminated Clays in the Glacial beds are worked at Limber and Kirmington, and perhaps also between Waltham and Barnoldby; but they are too exceptional and thin to be of economic importance anywhere else. In character they are very similar to the Humber Warp.

The Humber Warp makes an excellent tile and brick clay. This, and the convenience of being able to put the bricks directly into the barges, which can take them to almost any part of the Midland Counties, has caused a nearly continuous line of brick-yards and tile-kilns to be opened between Barton and New Holland. From New Holland to Cleethorpes, seven or eight other yards are also now at work. The pits are just inside the sea-bank, and are often sunk considerably below the water-level, and kept dry by pumping.

North of the Humber brick-yards in the Warp are not so extensive, and are apparently only used for the local supply of bricks, tiles, and drain pipes. Similar yards are also scattered over the Alluvial flats of the river Hull and its tributaries. These Alluvial Clays are usually stiffer and more carbonaceous than the Humber Warp.

ROAD METAL.

The larger stones from the Boulder Clay have been a good deal used for building, but they are now more commonly broken up for road metal. Until stopped by the Board of Trade, enormous quantities of shingle and boulders were gathered from the beach between Hornsea and Spurn, and shipped off or taken away by rail to various parts of Yorkshire. It is stated that at one time

the amount removed reached 40,000 or 60,000 tons per annum ;* but now little is taken, even north of Hornsea.

The loose stones off the fields are much used for road metal, and a good deal is also obtained from brick-yards, and from small pits in the Glacial Gravels. The stones from the beach were, however, much tougher, having undergone a process of "natural selection" which destroyed all the softer ones and found out any flaws.

Flint and Chalk from the Wolds are commonly employed, but though cheap are so splintery as to be of little use. They are usually only carried short distances over the low lands, but, where mixed with tougher material, the Chalk makes the roads bind well. Around Grimsby large quantities of the ballast brought by ships from the Baltic is used, and must not be confounded with the stones from the Boulder Clay. Great part of it is Basalt, Mica Schist, Garnetiferous Schist, Gneiss, &c., of a character unlike any yet seen in the Boulder Clay of Holderness. For many of the main roads with heavy traffic Leicestershire Granite has lately been introduced. It wears much better than any of the local material, but is expensive.

GRAVEL AND SAND.

Though a good many patches of Gravel and Sand have been mapped, few of them would yield a sufficient supply for any large engineering works. The only thick gravel at a convenient height above the Marsh to be worked is the Marine Bed described in Chap V. This forms isolated hills or long ridges, near Kelk and Brandeburton, and reappears over a considerable area around Kelsey Hill and Keyingham. At Kelsey Hill it has been very extensively dug for ballast, and another large pit, 40 feet deep, has lately been opened in it to supply ballast for the concrete at Hull Docks.

The same bed extends to Paull, but does not there rise so high above the Marsh. South of the Humber it extends from Goxhill to Grimsby, usually at a low level, though often worked in shallow pits. At Laceby it rises into a hill, and is a good deal dug to supply sand for building at Grimsby. Though the bed is found nearer, and even in the town itself, there is seldom more than four or five feet of it above the water-level.

These Sands, being generally full of specks of coal, cannot be used for plastering.

The later Gravels of Bridlington, Driffield, and Hornsea are commonly rougher, very full of Chalk, and often mixed with Clay or Marl. These, and the lenticular beds in the Boulder Clay, are only used locally.

* Coode, *Proc. Inst. Civ. Eng.*, vol. xxviii. p. 501; and Vetch, *ibid.*, vol. li. p. 205.

Sand from the Dunes along the coast is a good deal used at Hornsea, Grimsby, and Cleethorpes; but unless all the salt is washed out, it is very objectionable, as the houses never dry properly. It is also much used to mix with the stiffer Clays in brick-making.

HUMBER TUNNEL.

The question of a tunnel under the Humber having several times come up of late years, it may be advisable to point out what would be the probable character of the strata through which any tunnel must pass. Even if the alternative scheme of a bridge be adopted, it will still be necessary to obtain some idea as to the nature of the foundations. For this purpose all the borings likely to throw any light on the subject have been collected, and will be found in the Appendix. Mr. Kelsey has also obligingly supplied the details of a series of borings made by the North-eastern Railway Company between Hessle and Barton.

Unfortunately all the evidence seems to show that the valley of the Humber lies along a line of disturbance of some sort; it may be either a fault or a sharp anticlinal. The line for the base of the Chalk does not continue in the same direction across the Humber, as one would expect from the general direction and amount of the dip. Instead of making only a small bend towards the east, it sweeps round the foot of the Wolds for three miles past South Ferriby, and only turns northward at Barton Ferry. This singular course is proved by a number of wells bored on the Alluvial flat near Barton. Those south of the Chalk boundary engraved on the Map all touch Chalk; those north of it (eight in number) all miss the Chalk, but reach hard Secondary Clay, probably Kimeridge Clay.

Though this sudden change of strike is unexpected, Chalk-pits near Barton and Barrow confirm it. The dip, instead of being north-easterly, as in most parts of the Lincolnshire Wolds, is south-east, or directly away from the Humber. This seems to point to a tolerably sharp anticlinal in the bed of the estuary, or the line cannot join with the corresponding one on the north side. North of the Humber there seems to be a similar change in the dip and strike, the lines turning decidedly to the eastward, and the Chalk dipping north-east or north.

This structure seems to show that, under the Glacial Beds and Warp, we must expect, west of Barton Ferry, to find Kimeridge Clay instead of Chalk. East of the Ferry there would probably be Chalk, but along this line of disturbance it is likely to be broken up, loose, and full of water.

The solid rock will, in places, lie at a considerable depth beneath the present bed of the river, as the old Pre-glacial or Inter-glacial channel cuts much deeper than the present one. Unfortunately

all the borings along the line of section do not go sufficiently deep to touch the solid rock. But they prove that while near Hesle there is Chalk within less than 50 feet of the bottom of the river, yet there is an old deep channel, commencing about 25 chains from the Barton shore, with its bottom at least 84 feet below the present level of high-water.

The width and depth of this channel are both at present unknown. Though, from the fact that a boring at the farm a quarter of a mile due east of Bore-hole No. 5 reached Chalk at 90 feet below the Marsh, it seems probable that the channel is about a quarter of a mile wide, and not much over 100 feet deep in its deepest part.

If any attempt be made to tunnel under the Humber, it will be necessary to avoid the old Channel. A river bed like this must be continuous, and near its centre will everywhere cut to about the same depth, allowing for a slight fall towards the sea. Except immediately west of Barton we do not yet know its exact position, though it is apparently usually south of the deepest part of the present estuary.

The line of borings started 300 yards east of Hesle Ferry, and was carried straight across the Humber. East of the line, the old channel bends a little to the north, at Barton Ferry; for between the Ferry and New Holland rock is found at 50 feet. From Barrow Ferry it seems to correspond approximately with the present channel, for no trace of it appears in the numerous borings which have been made on the Barton and Barrow Marshes, and Chalk was reached within 30 feet of the Humber bottom at New Holland Pier Head.

At Killingholme Coast Guard Station the old channel appears again to touch the Lincolnshire shore, for no rock was found at 107 feet. Near Stallingborough Creek it has again turned northward, towards Sunk Island, and seems to pass under part of the Island, as a bore-hole did not reach rock at 114 feet. Unfortunately, the exact position of this bore cannot be ascertained. There may have been two ancient channels in this part of the Humber, as was the case within the last 200 years. Beyond Sunk Island the course of the buried channel is quite unknown.

The nature of the beds under the Humber can best be judged from the various sections noted in the Appendix. They all show constant alternations of soft Warp, 'Boulder Clay, Gravel, and running Sand. These alternations would render tunnelling very difficult, and make it impossible to obtain good foundations for piers without reaching the solid Chalk or Kimeridge Clay. Even in the deepest part of the buried channel there are no thick beds of Boulder Clay or Gravel.

Though the greatest depth of the buried channel probably does not exceed 120 feet below the level of high-water, it is still possible that there may be a narrow steep-banked gorge in the very centre. The whole of the evidence tends to contradict this idea; but before the real structure of the Humber Valley can be considered as satisfactorily demonstrated, it will be necessary

to obtain a series of borings closer together than those already made.

Beneath the Drift Deposits between Barton and Hessle there is generally shattered Chalk very full of water. This also ought to be avoided, and the tunnel carried as far as possible through the hard impervious Kimeridge Clay. In the Humber district there is no marly Lower Chalk, like that which is met with in the Channel Tunnel. The Chalk is hard and full of joints, which in a disturbed area like this are likely to be open fissures, and frequently are known to be so. The occurrence of ebbing and flowing wells on the marshes—occasionally with brackish water—seems also to show that the fissures are connected with the Humber through the pervious sandy Warp which fills the deepest part of the Post-glacial channel.

The best material for tunnelling would probably be the Kimeridge Clay; but to avoid tunnelling at a great depth the works should be constructed west of Barton and Hessle. Of course here the tunnel would be longer than if taken near the line of borings.

WATER SUPPLY.

The water supply of Holderness is mainly obtained from three sources;—natural springs from the Chalk, blow wells on the low lands, and artesian borings which tap the Chalk underlying the Drift. The first of these sources, perhaps does not come within the scope of the present Memoir, but as the streams from the Chalk flow across Holderness a short account will be given of them.

Along the eastern slope of the Wolds many powerful springs rise, but several of them being intermittent are quite untrustworthy for water supply. Commencing at the northern end of the district, at low tide strong springs are given out from the Chalk on the foreshore north of Bridlington. From their inconvenient position these cannot be used, though they are well known to the fishermen.

A stream of considerable size, called the Gipsey Race, flows through Bridlington Quay, and helps to scour the Harbour. It rises in the Wolds about ten miles away, near Wold Newton, and, though partially intermittent, seldom runs entirely dry.

At Bessingby, Burton Agnes, Kilham, and Ruston there are small springs, and at Nafferton there is one of some importance.

Near Great Driffield the River Hull takes its rise in Emswell or Driffield Beck. The large amount of water given out in this neighbourhood is apparently due to the change of strike of the Chalk, which dips towards Driffield both on the north and west. Several minor streams, known as the Gipsey Race, Eastburn Beck,

Southburn Beck, and Wellsprings Drain, also flow into the Hull at Driffield.

South of Driffield, Wear Bracken Beck, Bryan Mill Beck, Scorbrough Beck, and other small streams, flow from the Chalk, but Beverley and Cottingham are both almost entirely supplied from wells. Hull obtains its water from large springs and wells at the foot of the Wold at Spring Head, near Anlaby.

On the south side of the Humber, springs from the Chalk are rare, most of the water apparently passing through the Glacial Gravels before it appears at the surface. A small beck flows through Swallow, but is usually lost before it reaches the clay lands. In winter it rises again at the foot of the Wold, and forms the northern branch of Laceby Beck.

The main source of Laceby Beck is, however, at Wellbeck, near Barnoldby. At this point there is a semi-circular hollow, about 100 yards across and 15 feet deep, resembling an old chalk-pit, though probably natural. The Beck does not usually rise here in summer, but towards winter it suddenly bursts out in full force. At the time of my first visit, on October 3rd, 1882, there was no water in the pit, but a small muddy hollow at the bottom was covered with an abundance of thriving Forget-me-not, proving that it is seldom quite dry. The dry stream bed leading from the pit, judging from its width and gravelly bottom, must in rainy seasons contain a considerable beck, but was then quite dry in its upper part. About 8 chains from the source there was a little standing water, but no stream; below this point, at short distances apart, there were small pools. At 26 chains from Wellbeck, in a straight line, there was a very small but perceptible stream, and from the abundance of stickleback it seems that the bed is here seldom entirely dry. Evidently the water-level was everywhere within a few inches of the surface, and the slightest rise would cause an abundant overflow.

On December 10th of the same year Wellbeck was revisited. Strong springs were flowing from all parts of the hollow, and the stream as it left the pit was as large as the lower part of Laceby Beck is in summer. The exact date of the outbreak in that year could not be ascertained.

Intermittent springs from the Chalk occasionally break out much higher up the Dales after long-continued heavy rain. When this happens they may cause much mischief from walls or farm-buildings having been built across the bottom of the dry valleys. An account of these exceptional floods will be found in the Geological Survey Memoirs relating to the Wolds, where also a fuller description of the Chalk springs will be given.

Few natural springs of importance are found in the lowlands of Holderness, except south of the Humber. The small springs that rise in the glacial beds are of little value, and usually the water is strongly impregnated with lime or iron, sometimes so much so as to be quite undrinkable.

In one or two places north of the Humber, and more abundantly in North Lincolnshire, the so-called "Blow Wells" occur. These are springs which rise through Drift or Alluvium in the middle of the flat lands. They generally bubble up from the bottom of small pools of perfectly clear water, and are connected with some porous bed considerably beneath the surface. The name probably refers to the constant play of the white sand at the bottom of the pools; for bubbles of gas are only disengaged in a few of them, and not, as far as I have seen, in the larger ones.

South of the Humber there is a Blow Well about a mile west of Barton, and another a mile east of the village, on the Warp. Perhaps the southern branch of Barrow Beck also rises in one, but there are also a number of artificial wells to supply the water-cress beds.

Along the course of the Ulceby Beck there are several Blow Wells, which apparently rise out of the Inter-glacial Gravels, where they pass under the Boulder Clay. Two of these are on the Alluvium at Thornton Moor, and there is a group on the Alluvium south of Ulceby; these latter may rise either from the Gravels or directly out of the Chalk.

Keelby Springs also rise near the point where the Boulder Clay overlaps the Gravels, and so does a Blow Well on the Alluvium north of Laceby. Along Laceby Beck there are several Blow Wells, all probably rising from this bed of Gravel, which must be close to the surface, though not always actually bare.

Between Grimsby and Little Coates lie the group of Blow Wells which now supply Grimsby with water. They form several pools of clear water, which yield a supply sufficient for the town, though a great deal runs to waste. These Wells are more than three miles from the bare Chalk, but they occur at a point where the Inter-glacial Gravels again outcrop.

The origin of the Blow Wells just described is not satisfactorily made out, for the bed of Gravel from which they appear to spring has a small outcrop, and is quite incapable of yielding so large a supply of water; there is also no evidence of direct connection with the underlying Chalk. The most probable explanation is that the water is Chalk water, not obtained direct, but flowing for a mile or more through the Gravel, which abuts against the buried Chalk cliff below the line of saturation. The thinning-out, and over-lap of this Gravel as we go eastward will account for the same springs not being tapped in the numerous borings which pass through the Boulder Clay, and obtain their supply from the Chalk. Occasionally the springs are tapped. Mr. Cordeaux, on deepening the cellar of his house at Great Coates, broke into a bed of sand, which yielded so copious a supply of water that it needed the laying down of a special drain to carry it away.

Close to Tetney there is a group of seven or eight Blow Wells on the Warp, the origin of which is much more difficult to understand. A farmer stated that he had lowered a heavy weight to a great depth in one of them, and found no bottom. There is also no trace of the Gravel in the immediate neighbourhood; and

Mr. Jackling states that close to the Wells he bored 63 feet in clay before reaching the Chalk, and at Tetney village there was 81 feet of clay. From this it would appear that at Tetney Blow Wells the water must rise direct from the Chalk. How the water has penetrated the 63 feet of clay is not clear, but probably these Wells originated when the land was at a higher level, and instead of an Alluvial flat at this point there was a steep-sided valley cut 40 or 50 feet lower,—perhaps sufficiently low to tap the Chalk or an immediately overlying sand bed.

Though the natural water supply of Holderness is, as a rule, not good, an artificial supply is so easily obtained, and the mode of obtaining it is so well understood, that nearly every farm has a well down to the Chalk.

These wells are usually bored through an average thickness of 70 or 80 feet of Drift or Warp, and water is generally found within 20 feet of the top of the Chalk. On the low grounds the water often overflows at the surface directly the Chalk is reached. The borings are made very cheaply, so much so that six or seven have been made merely to supply the watercress beds at Barrow. As the cost is much less than the usual price for boring 100 feet in other parts of England, the Holderness system might with advantage be introduced in other low-lying districts where there is a similar geological structure, such as East Norfolk.

Very thin lining tubes are used, and are driven down as the work advances, so as always to be within a short distance of the bottom, the tubes being lengthened at the same time by sections soldered on above. Very little force is used in driving down the lining, and apparently only a dead weight is employed, as the tubes would not stand any violence. The rapidity with which these borings are made seems to allow no time for the clay to close in and grasp the tube. Probably it is this rapidity and fairly constant motion which allows such thin lining to be used even for considerable depths.

Details of a number of these borings will be found in the Appendix. Few fail to obtain good water, except in Sunk Island, where the water is brackish.

At Bridlington a boring in the harbour yields a good supply of water. The quality is excellent, though the level rises and falls with the tide. South of the harbour there is another well, connected with a stand pipe. This yields no water at low-tide, but at about half-tide it commences to flow, and continues till the tide again falls to the same level. The spring in the harbour is largely used for the supply of the town, and is preferred to the natural springs.

Analyses of the water obtained on January 11th, 1873, were made for the Rivers Pollution Commission, with the following result:—

* "Rivers Pollution Commission," Sixth Report, p. 123.

		Boring in the Harbour. (Temperature 97° C.)	Natural Springs. (Temperature - 85° C.)
Total Solid Impurity	-	25.36	30.76
Organic Carbon	-	.032	.055
Organic Nitrogen	-	.006	.009
Ammonia	-	.0	.0
Nitrogen as Nitrates and Nitrites	-	.358	.573
Total Combined Nitrogen	-	.364	.582
Previous Sewage or Animal Contamination	3.260		5.410
Chlorine	-	2.25	3.20
Hardness, temporary	-	14.5	18.9
permanent	-	5.4	5.0
total	-	19.9	23.9

Both waters are clear and palatable.

Hornsea is still supplied from private wells, but the amount obtained is insufficient. A few years ago a deep well was sunk and bored at Leys Hill, to supply the village, but the water obtained is strongly ferruginous and quite undrinkable. Ferruginous water from the Chalk is so unusual that at first it seemed that a spring from the Glacial beds must have got in, but portions of the borings preserved show seams of ferruginous marl in the Chalk. Another boring in Hornsea, at Mr. Wade's brick-yard, was carried down to a depth of 976 feet without obtaining water or piercing the upper Chalk. This well, notwithstanding its great depth, was entirely bored by hand, and was only abandoned when it was found that a steam engine must be employed.

Withernsea is supplied from private wells, as are all the other villages in Holderness which are not close to the Wolds.

At Sunk Island the water from the Chalk is brackish. But this does not appear to be the case elsewhere on the borders of the Humber, for there are numerous wells of good water on the warp lands of Lincolnshire. No attempt appears to have been made to reach the Chalk at Spurn Head, and water has to be brought several miles. Notwithstanding the position of the head it is quite possible that the Chalk may yield a good supply. Chalk would probably be found at a depth of 100 or 120 feet.

Wells on the Humber Warp near Great Coates are sometimes affected by the tide, but none of them appear to be brackish.

Close to the pier at Cleethorpes there is a boring which supplies a drinking fountain. Formerly this yielded 200 gallons in five minutes, overflowing two feet above the surface; but the supply is now much less, the bore having apparently become clogged. Another boring at Cleethorpes, in the bed of the Humber, 400 yards below high-water mark, yielded 100 gallons per minute, forcing a jet 16 feet higher than the ground. There is another similar well on the warp near Humberstone.

With the exception of the ferruginous water of Hornsea and the brackish water of Sunk Island, all the deep wells or strong springs in Holderness yield water of a very similar character. The following analysis of the water from the Grimsby Blow-Wells shows that there is very little difference between wells at opposite

ends of the district. Like the former analyses this is taken from the Report of the Rivers Pollution Commission.

						Grimsby, 10th Jan. 1873. (Temperature, 72° C.)
Total Solid Impurities	-	-	-	-	-	27.26
Organic Carbon	-	-	-	-	-	.028
Organic Nitrogen	-	-	-	-	-	.003
Ammonia	-	-	-	-	-	.001
Nitrogen as Nitrates and Nitrites	-	-	-	-	-	.267
Total Combined Nitrogen	-	-	-	-	-	.271
Previous Sewage or Animal Contamination	-	-	-	-	-	2.360
Chlorine	-	-	-	-	-	1.80
Hardness, temporary	-	-	-	-	-	14.3
permanent	-	-	-	-	-	6.3
total	-	-	-	-	-	20.6

APPENDIX I.

WELL SECTIONS AND BORINGS.

With one or two exceptions, the whole of the following are borings. The exact character of the beds cannot always be ascertained, as the material brought up is a good deal mixed, and is seldom preserved. Notes in square brackets are my own. The sections marked [S.V.W.] were collected by the late S. V. Wood, who handed them to Mr. Dalton for the use of the Geological Survey.

ASHBY-CUM-FENBY. $\frac{1}{2}$ mile N.W. of the Church.

Communicated by MR. WESTABY.

	FEET.
Clay with Chalk stones [Boulder Clay]	120
Chalk.	

The surface is about 30 feet above the stream.
Water rises to within 30 feet of the surface.

BARROW. At Mr. Westaby's house.

Communicated by MR. WESTABY.

	FEET.
Clay and stones	15
Gravel	6
Clay	8
Gravel	13
To Chalk	42

BARROW Market Place.

Communicated by MR. WESTABY.

	FEET.
Clay	9
Gravel	12
Clay	21
Gravel	15
To Chalk	57

BARROW Beck (unfinished boring).

Communicated by MR. WESTABY.

	FEET.
Loam	4
Gravel	2
Sand	1
Gravel	2
Clean clay	3
Gravel	13

BARROW. On the Goxhill Road, about $\frac{1}{2}$ mile from Barrow.

Communicated by MR. WESTABY.

	FEET.
Clay	18
Sand	18
Clay	10
To Chalk	46

The bed of sand extends continuously for about a mile further east.

BARROW Ferry, E. side.

Communicated by MR. WESTABY.

	FEET.
Rock at (all Warp)	70

BARROW Ferry, W. side.

	FEET.
Rock at (all Warp)	90

BARROW Ferry, Farm 1 mile W. of.

Communicated by MR. WESTABY.

	FEET.
Warp, &c.	78
Sand (rough)	12

To Chalk	90
	—

BARTON. Newport.

Communicated by MR. WESTABY.

	FEET.
Clay	21
Gravel	6

To Chalk	27
	—

BARTON. Lower end of Fleetgate.

Communicated by MR. WESTABY.

	FEET.
Clay and stones	
Gravel about 3 feet	40
Clay	
Chalk	

BARTON Water Side, several wells at the Brick Yards E. of, and at the Malt Kilns.

Communicated by MR. WESTABY.

	FEET.
Warp	about 78
Sand (rough)	12
To Chalk	90

BARTON Water Side, well 50 chains W. of.

Communicated by MR. WESTABY.

	FEET.
Warp	about 70
Sand (rough)	20
Blackish or brown clay [Kimeridge ?], only touched	—
	90

Water was obtained from the sand.

BARTON Water Side, well $\frac{1}{4}$ mile W. of.

Made by a Hull borer, but communicated by MR. WESTABY.

	FEET.
Warp	70
Sand	20
Clay, black and hard [Kimeridge]	—
	90

BARTON. N. side of the Ings Lane. Eight borings.

Communicated by MR. WESTABY.

	FEET.
Warp, &c. to clay [Kimeridge]	90
BARTON Gas Works.	
Communicated by MR. WESTABY.	
	FEET.
Warp with one or two sand beds	45
Chalk	15
	<hr/> 60

BARTON. At the Ropery Engine House.

Communicated by MR. WESTABY.

	FEET.
Warp and fine sand	50
Chalk	49
Clay [Kimeridge]	<hr/> 99

BARTON. High Street.

Communicated by MR. WESTABY.

	FEET.
Hard clay with Chalk	from 9 to 30
Chalk	

BARTON. At the junction of King Street and High Street, in a channel in the Chalk.

Communicated by MR. WESTABY.

	FEET.
Clay and Chalk	30
Gravel	33
To Chalk	<hr/> 63

BARTON. At the junction of King Street, and Marsh Lane.

Communicated by MR. WESTABY.

	FEET.
Clay and Chalk	36
Gravel	15
To Chalk	<hr/> 51

BARTON. Whitecross Street.

Communicated by MR. WESTABY.

Rock at the surface: 18 feet to water.

BARTON. Well at the house W. of Mount Close.

	FEET.
Clay [Boulder Clay?]	15
Chalk	<hr/> —

BEEFORD. Close to Moor Grange.

Communicated (to MR. DAKYNS) by MR. WATSON, of Moor Grange.

	FEET.
Blue Clay with whitey [chalky Boulder Clay?]	120

BEVERLEY PARK.

Communicated (to MR. DAKYNS) by MR. VILLIERS.

	FEET.
Red clay	15
White gravel	15
To Chalk	30

BRANDSBURTON Village.

Prestwich, *Quart. Journ. Geol. Soc.*, vol. xvii. p. 446.

	FEET.
Gravel (marine)	10 or 12
Boulder Clay	60
Flinty Gravel	8 or 10
To Chalk	about 80

BRIDLINGTON Harbour.

	FEET.
Boulder Clay	28
Hard Conglomerate of chalk and flint	15
To Chalk	43

BROCKLESBY HALL.

Communicated by MR. WESTABY.

	FEET.
Sand	9
Clay	21
To Chalk	80

BURSTWICK Station.

Prestwich, *Quart. Journ. Geol. Soc.*, vol. xvii. p. 446.

	FEET.
Brick clay [Warp]	7
Strong Marl with "ironstone" [Boulder Clay]	29
Strong Marl with stones [Boulder Clay]	40
Red Sand, giving sufficient water	—
	76

CATFOSS.

Communicated (to MR. DAKYNS) by MR. VILLIERS, of Beverley.

	FEET.
Clay	28
Sand with shells	3
Clay with layers of sand	10
Boulder Clay with boulders as big as a thirty-gallon cask	45
Warp Clay	20
White Marl [Chalk ?]	12
Chalk	—
	118

CLEETHORPES. North end of the cliff, and close to the pier.

From MR. PENNING'S notes.

	FEET.
Boring into the Chalk	204

Formerly yielded 200 gallons in 5 minutes. The water overflows 2 feet above the surface. [The supply is now much smaller.]

CLEETHORPES Pier (from half tide).

Communicated by MR. JOHN SMITH.

	FEET.
Marl clay	60
Soft white Chalk with flints	—

One boring at Cleethorpes sunk 45 feet in soft Chalk.

CLEETHORPES. At the Gas tank.

Communicated by MR. JOSEPH JACKLING.

	FEET.
Warp	about 20
Clay [Boulder Clay] with vein of sand 1½ yards thick at 15 yards	72
Sand	2
Chalk (soft like putty)	—
To Chalk	about 94
Chalk (soft like putty)	39
	<u>133</u>

CLEETHORPES. At first Brick-yard on the Humber Shore W. of the village.

	FEET.
Clay, to Chalk	120

CLEETHORPES, in the bed of the Humber, 400 yards below high-water mark.

Communicated by T. W. WALLIS, Esq. (to MR. JUKES-BROWNE).

	FEET.
Rock at	72
In Chalk	21
Yielding 100 gallons per minute, forcing a jet 16 feet higher than the ground.	

COTTINGHAM. Mr. Witty's land.

From a letter from MR. E. WITTY to REV. J. L. ROME, communicated by MR. S. V. WOOD, jun. (to MR. DALTON).

	FEET.
Soil	2
Sand and Gravel	16
Marl or red Clay	8 or 9
Quicksand	15 or 20
Yellow Clay	2 or 3
To Chalk	<u>43</u>

COTTINGHAM. Thwaite Street. Same source.

	FEET.
Sand and Gravel, to Chalk	40

COTTINGHAM. De-la-pole Grange. Same source (bored by Agar).

	FEET.
Red Clay	50

COTTINGHAM. Brick-yard one mile east of, on the Hull Road.

Bored and communicated by MR. BRUMBY (to MR. DAKYNS).

	FEET.
Alluvium	4
Peat	1
Gravel	8 or 10
Soft Clay and Chalk [Boulder Clay] not through	—
	<u>18</u>

COTTINGHAM. Well at the Brick-yard one mile east of.
Same source.

		FEET.
To Chalk		56
Chalk		14
		—
	70	

COTTINGHAM Church.
From MR. DAKYNS' notes.

	FEET.
To Chalk	30

DANES DIKE.

Communicated by MR. VILLIERS (to MR. DAKYNS.)

	FEET.
Strong clay	25
Running sand	7
Blue clay	4
Dark sand	1
Blue clay	5
Red clay	1
Gravel	2
Bubble Chalk	2
	—
To hard Chalk	47

DONNA NOOK.

Communicated by MR. W. SARGENT.

	FEET.
Silt (blowing)	30 or 33
Black mud	21
Clay and Sand	60

To Chalk	about	112
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FULSTOW.

Communicated by MR. W. SARGENT.

	FEET.
Boulder Clay	60
Chalk	—

GEMBLING.

	FEET.
Strong red clay	10
Sand and gravel	6
Blue clay	56

To Chalk	—	72
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GOXHILL Marshes, S. part of. Several wells.

Communicated by MR. WESTABY.

	FEET.
Warp	about 5
Chalk	—

GOXHILL Marshes, S. part of. Several wells.

Communicated by MR. WESTABY.

	FEET.
Warp	about 60
Chalk	—

GOXHILL Marshes, $\frac{1}{2}$ m. N.E. of Ox Marsh Farm.

Communicated by MR. WESTABY.

		FEET.
Warp	· · · · ·	about 50
Chalk	· · · · ·	—

GOXHILL Marshes. At Ox Marsh Farm.

Communicated by MR. WESTABY.

		FEET.
Warp	· · · · ·	—
Strong red clay with Chalk	· · · · ·	27
Chalk	· · · · ·	—

GOXHILL, near the Station.

Communicated by MR. WESTABY.

		FEET.
Clay	· · · · ·	48
Chalk	· · · · ·	—

GOXHILL Priory.

Communicated by MR. WESTABY.

		FEET.
Hard clay with stones	· · · · ·	45
Chalk	· · · · ·	—

GOXHILL. Littleworth.

Communicated by MR. WESTABY.

		FEET.
Clay	· · · · ·	39

GRAINSBY HALL.

Communicated by MR. JOSEPH JACKLING.

		FEET.
Strong clay	· · · · ·	about 84
Chalk	· · · · ·	—

GREAT COATES. Mr. Cordeaux's.

Communicated by MR. CORDEAUX.

		FEET.
Boulder Clay, 8 feet }	· · · · ·	—
Sand (thick bed) }	· · · · ·	66
Boulder Clay - - - - -	· · · · ·	—
Chalk	· · · · ·	—

The house is about 9 or 10 feet above the marsh level. Similar sections occur all over Great Coates. On the marshes a boring, midway between the railway and the Humber bank, made by Mr. Cordeaux in July 1885, passed through:—

		FEET.
Clear warp with a cockle shell	· · · · ·	12
Forest bed	· · · · ·	2½
Whitish Clay and sand [old soil ?]	· · · · ·	1
Chalky Boulder Clay, reddish at top, darker lower down, the lowest part not unlike the lower bed at Dimlington in colour	· · · · ·	55 or 60
Sand and gravel	· · · · ·	2 or 3
Chalk	· · · · ·	—

Many of the wells at Coates are affected by the tides, the flow decreasing at neap tides, though the water is perfectly fresh.

GRIMSBY. Borings for the water-works.

Bored and communicated by MEASRS. MATTHEW & PLATT (to MR. C. E. DE RANCE). First bore-hole west of Grimsby.

	FEET.
Very soft clay, full of vegetable matter	21
Gravel and sand	3½
Clay	5
Rough gravel and small flints	2
Fine soft clay and small flints	2
Rough gravel	11½
Fine gravel	15
To Chalk	60
Chalk, very hard	15
	<u>75</u>

Water rose from the chalk 4 feet above ground in any quantity. At 24 feet from the surface there is only a yield of from 7,500 to 8,000 gals. per hour.

Second bore-hole east of Grimsby (Cleethorpes).

	FEET.
Stiff bluish-brown clay with flakes of Chalk and a few fossils	84
Sand and gravel	15
To Chalk	99
Chalk and Flints, in beds	125
	<u>224</u>

The top of the Chalk is very rotten and seems to be all broken up; it had to be tubed out to 120 feet from the surface.

GRIMSBY. On the Marshes.

Communicated by MR. W. SARGENT.

	FEET.
Wood at	27
To rock	78

GRIMSBY.

Communicated by MR. SARGENT.

	FEET.
To Chalk	about 66

GRIMSBY. On the Humber shore near the new timber ponds.

Communicated by MR. MAUGHAN.

No. 1.

	FEET.
Blue clay	18
Black peat	1½
Sand and gravel	1½
Marsh clay (brown)	8
	<u>29</u>

No. 2.

							FEET.
Blue clay	-	-	-	-	-	-	24
Peat	-	-	-	-	-	-	seam
Silt and water	-	-	-	-	-	-	3
Blue clay	-	-	-	-	-	-	—
							27

No. 3.

							FEET.
Good blue clay	-	-	-	-	-	-	30
Peat	-	-	-	-	-	-	1
Brown clay	-	-	-	-	-	-	—
							31

HEDON Station.

PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. xvii. p. 456.

							FEET.
Brick clay [Warp]	-	-	-	-	-	-	6
Grey marl with stones [Boulder Clay]	-	-	-	-	-	-	24
Sand, with water	-	-	-	-	-	-	—
							30

HEDON. At Old Pollard Farm.

PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. xvii. p. 455.

							FEET.
1. Soil	-	-	-	-	-	-	2
2. Red brick-clay	-	-	-	-	-	{ [Recent Warp]	4
3. Black warp	-	-	-	-	-		34
4. Red clay full of stones [Boulder Clay]	-	-	-	-	-		20
5. Rough gravel with sand and spa-water	-	-	-	-	-		26
6. Very fine clay, clear of stones	-	-	-	-	{ [Inter-glacial		8
7. Bed of flint	-	-	-	-	beds ?]		2
8. Black moor, decayed wood	-	-	-	-			2
9. Blue clay with white sand	-	-	-	-			1
10. Blue clay with white marl	-	-	-	-	{ [Boulder Clay]		8
11. White marl-clay with cobbles and flints	-	-	-	-			9
12. Chalk with bed of sand	-	-	-	-			5
13. Chalk clear of flint	-	-	-	-			69
							190

HEDON. At Twyer's Farm.

PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. xvii. p. 455.

							FEET.
1. Soil	-	-	-	-	{ [Recent Warp]		2
2. Good brick-clay	-	-	-	-			5
3. Black warp	-	-	-	-			13
4. Strong marly clay with stones [Boulder Clay ?]	-	-	-	-			40
5. Rough gravel-stones and spa-water	-	-	-	{ [Inter-glacial			24
6. Fine clay	-	-	-	Beds ?]			1
7. Dark green sand	-	-	-				11
9. Blue clay with white sand	-	-	-	{ [Boulder			2
10. Hard mixture of blue clay and white marl	-	-	-	Clay ?]			12
11. Red clay with white marl	-	-	-				10
12. Chalk	-	-	-				7
13. White sand which blew up into the pipes 20 feet high	-	-	-				1
14. Chalk clear of flints	-	-	-				50½
							178½

Twyer's Farm lies a quarter of a mile from the edge of the Marsh. Pollard Farm is half a mile west-south-west of Twyers, and close to Hedon Haven.

HESSLE.

	FEET.
Clay, to Chalk	18

HOLTON SKITTER. Tile kiln 1 mile S.E. of.

Communicated by MR. WESTABY.

	FEET.
Warp Chalk	about 55

HOLTON SKITTER Kilns.

Communicated by MR. WESTABY.

	FEET.
Warp Chalk	about 60

HORNSEA. At Mr Bateson's, between the Waterworks and Atwick Mill.

Communicated by MR. EVISON.

	FEET.
Clay	115
Gravel and sand	20
To Chalk	<u>135</u>

HORNSEA. At Mr. Aller's.

Communicated by MR. EVISON.

	FEET.
Sand and Gravel	20
Hard marl and Chalk	about 15
Running sand	20
Marl clay	?
Sea gravel	?
To Chalk	<u>110</u>

HORNSEA. Mr. Wade's Brick-yard.

Communicated by MR. EVISON.

	FEET.
To Chalk (all clay)	110 or 120

HORNSEA. Mr. Wade's Brick-yard.

Communicated by MR. J. SMALLEY.

	FEET.
Chalk without flints, base not reached. No water	976

HORNSEA. Mr. Wade's Brick-yard, 1864-65.

Information from G. SMALLEY, sinker. [S. V. W.]

		FEET.
Grey marl	-	15
Red sand	-	5
Marl	-	80
Red sand	-	8
	To Chalk	108
Soft rock	-	382
Hard Chalk with a band of Fuller's earth at 550 feet	-	105
Fuller's earth	-	5
Chalk with occasional bands of "Fuller's earth"	-	305
	No water at	905
		<hr/>

HORNSEA. Mr. Wade's Hall ($\frac{1}{2}$ mile N. of Hornsea and 1 mile W. of Cliff). 1860.

Information from G. SMALLEY, sinker. [S. V. W.]

		FEET.
Clay	-	10
Red sand	-	4
Marl	-	26
Grey marl	-	4
Sand and Gravel	-	29
Red marl [Boulder Clay]	-	29
Gravel and Sand	-	8
Conglomerate	-	2
Fine sand	-	3
	To Chalk	115
	In Chalk	56
		<hr/>
		171
		<hr/>

HORNSEA.

Messrs. Wood and Rome, *Quart. Journ. Geol. Soc.*, vol. xxiv. p. 146.

Several borings gave Chalk at 60 or 70 feet below the sea-level.

HORNSEA. New Inn.

Messrs. Wood and Rome, *Quart. Journ. Geol. Soc.*, vol. xxvi. p. 146.

		FEET.
Gravel, the upper 60 feet yielding small shells	-	161
Chalk	-	<hr/>
[? If trustworthy.]		

HORNSEA Station.

Communicated by Mr. J. SMALLEY.

		FEET.
To rock	-	93
Chalk	-	40
		<hr/>
		133
		<hr/>

HORNSEA BRIDGE. Mr. Wade's new houses. 1862.

Information from G. SMALLEY, sinker. [S. V. W.]

		FEET.
Sand		4
Grey Clay		9
Gravel		19
Marl [Boulder Clay]		22
Gravel		2
Clay [Boulder Clay]		58
		<hr/>
To Chalk		114
In Chalk		47
		<hr/>
		161
		<hr/>

HULL. New Forge, near St. Paul's. 1860.

G. SMALLEY, sinker. [S.V.W.]

		FEET.
[Alluvium, { Clay		10
22 feet.] { Black Warp		10
} Sand and Gravel		2
Marl [Boulder Clay]		25
Sand and Gravel		6
		<hr/>
To Chalk		53
In Chalk		113
		<hr/>
		166
		<hr/>

HULL. Holderness Road. 1863.

G. SMALLEY, sinker. [S.V.W.]

		FEET.
[Alluvium, { Clay		35
56 feet.] { Sand and Clay		21
[Drift, { Marl [Boulder Clay]		20
29 feet.] { Sand and Gravel		9
		<hr/>
To Chalk		85
In Chalk		44
		<hr/>
		129
		<hr/>

HULL. West Rod. 1862.

G. SMALLEY, sinker. [S.V.W.]

		FEET.
Alluvium, { Clay		8
26 feet.] { Dark sand		17
} Peat		1
[Drift, { Clay		45
57 feet.] { Red Clay		9
} Sand and Gravel		8
		<hr/>
To Chalk		88
In Chalk		304
		<hr/>
		387
		<hr/>

HULL. Mr. Oxby's, near Samuelson's Works. 1863.
G. SMALLEY. [S.V.W.]

		FEET.
[Alluvium, 30 feet.]	{ Clay Black sand Peat	about 15 5 1
[Drift, 75 feet.]	{ Gravelly Clay Marl [Boulder Clay] Sand and Gravel	9 about 55 20
	To Chalk	" 105
	In Chalk	" 175
		280
		280

HULL. Stone Ferry. Waterworks. 1858.
G. SMALLEY. [S.V.W.]

		FEET.
Alluvium, { Clay 25 feet. { Warp	about 15 " 10	
Drift, 25 ft. Marl [Boulder Clay]	" 25	
	To Chalk	50
	In Chalk	181
		231
		231

HULL. North Bridge, Lime Street.
G. SMALLEY. [S.V.W.]

		FEET.
[Alluvium, 38 feet.]	{ Clay Warp and dark sand Gravel and sand	about 12 16 10
[Drift, 39 feet.]	{ Marl [Boulder Clay] Sand and Gravel	27 12
	To Chalk	77
	In Chalk	54
		131
		131

HULL. Derringham Street, near Cemetery. [S.V.W.]

		FEET.
Stiff clay		7
Warp, sand and mud		35
Peat, very solid		3
Gravel and red sand		5
	To Chalk	50
		50

HULL. Dairycoates.

Wood and Rome, *Quart. Journ. Geol. Soc.*, vol. xxiv. p. 146.

		FT. IN.
Warp		20 0
Peat		2 0
Clay with small checkers (Hessle clay)		19 6
Sand with small shells (Hessle sand)		12 6
	Chalk	at 54 0
		54 0

HULL. On the foreshore at Dairy Coates Grange.

Communicated by MR. HURSTWITZ, Resident Engineer, Hull and Barnsley Railway (to MR. CAMERON).

	FEET.
Alluvial deposits	46
Drift	45
Chalk	235
	<hr/>
	325
	<hr/>

HULL. Blundell's Oil Mill, Wincolmlee. 1863-64.

Information from G. SMALLEY, sinker. [S.V.W.]

	FEET.
Clay (Hessle Clay ?)	13
Sand and Gravel	16
Marl (Purple Clay)	24
Gravel	7
	<hr/>
To Chalk	60
Rock [Chalk ?]	390
Grey hard Chalk	146
Blue Bind [Kimeridge Clay ?]	20
	<hr/>
No water at	616
	<hr/>

HULL. Blundell's New Mill, Groves. 1864-65.

Information from G. SMALLEY, sinker. [S.V.W.]

	FEET.
Clay	12
Black Warp	18
Sand and Gravel }	18
Marl (Purple Clay)	20
Sand and Gravel	5
	<hr/>
To Chalk	55
In Chalk	151
	<hr/>
	206
	<hr/>

HULL. Darling's, High Street.

Communicated by MR. J. SMALLEY.

	FEET.
To rock	100

HULL. Wincolmlee.

Communicated by MR. J. SMALLEY.

	FEET.
To rock	74
A 16165.	K

HULL. Block House Mill.

PROF. PHILLIPS, *Illustrations of the Geology of Yorkshire*, Pt. I. ed. 3, p. 66.

		FT. 1 IN.	FEET.
Alluvial Deposit.	Soil	1 0	
	Clay	6 0	
	Silt sand	23 0	
	Moor and peat, with large trees &c.	2 0	
Diluvial Deposit.	Blue clay	1 6	Mixed with chalk fragments, carbonized wood, &c.
	Brown clay	22 6	
	Loamy clay	12 0	
	Quicksand	26 0	
	Chalk		16
			110

HULL. No. 1. B. H. $\frac{1}{2}$ -mile east of Springhead Pumping Station and on the waterway to Hull (obtained by MR. A. G. CAMERON).

		FEET.
Well	Soft marly clay warp	50
Bore	{ Chalk	350
	{ Clay, Kimeridge probably	—
		400

HULL. Springhead new Waterworks.

Information from MR. DALE. [S.V.W.]

		FEET.
Well		15
Strong marl		6
Soft rubbly Chalk		9
Strong rubble Chalk (?) if in place)		—
To Chalk (certain)		40

HULL. Springhead Waterworks.

Communicated by MR. J. SMALLEY.

		FEET.
Marl [Boulder Clay]		about 14
Chalk		411
Clay [Kimeridge (?)]		—

HULL. Danson Lane.

Communicated by MR. J. SMALLEY.

		FEET.
Warp Clay		
Boulder Clay		
Gravel		
Boulder Clay		
Chalk		110
		162

HULL. Jamieson's, Cannon Street.

Communicated by MR. J. SMALLEY.

		FEET.
Warp and Boulder Clay		62
Chalk (base not reached)		355
		417

HULL. By the Hydraulic Station at end of the New Graving Dock.

Communicated by MR. J. SMALLEY.

	FEET.
To rock	92
Chalk	235
	327

HULL. The Groves.

Communicated by MR. J. SMALLEY.

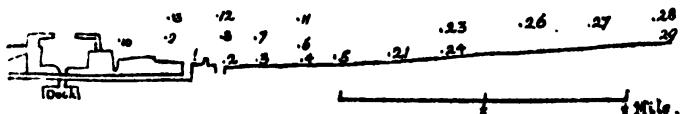
Two borings;—one 64 feet to rock, the other 70 feet to rock.

HULL. Thomas Street.

Communicated by MR. J. SMALLEY.

	FEET.
To rock	76

FIG. 11.—Position of borings on the Humber foreshore.



HULL. Borings on the shore west of Humber Docks. [S.V.W.]

Datum line high-water mark.

	No. 1.	No. 2.	No. 3.
	FEET.	FEET.	FEET.
Water	5	5½	10½
Slake and Sand	25	19½	9½
Black peat	2	4	4½
Strong stony Clay	10	not stated	8½
Wet Sand	1	—	10½
Strong stony brown Clay	20	—	not stated
Clay with sand threads	8		
Wet Sand	16		
Chalk rubbish and Sand	16		
To Chalk	103		
In Chalk	5		
	108		

No. 4.

	FEET.
Water	12½
Slake and Sand	8
Soft stony brown Clay	3
Strong stony brown Clay	10½
Wet sand	10½
To strong stony brown Clay	44½

		No. 5.	No. 6.	No. 7.
		FEET.	FEET.	FEET.
Water	-	12 $\frac{1}{2}$	18 $\frac{1}{2}$	20 $\frac{1}{2}$
Slake and Sand	-	8	wanting	wanting
Strong stony brown Clay	-	6 $\frac{1}{2}$	8	10
Wet Sand	-	15	16 $\frac{1}{2}$	11 $\frac{1}{2}$
Strong stony brown Clay	-	20	18 $\frac{1}{2}$	22
Clay with Sand threads	-	11 $\frac{1}{2}$	7	not stated
Chalk rubble and Sand	-	3	1	
Wet Sand	-	3	—	
		<u>79$\frac{1}{2}$</u>	<u>69$\frac{1}{2}$</u>	

		No. 8.	No. 9.
		FEET.	FEET.
Water	-	20 $\frac{1}{2}$	19 $\frac{1}{2}$
Silt	-	wanting	14
Peat	-	5	2
Soft stony brown Clay	-	4	5
Strong stony brown Clay	-	9	4
Wet Sand	-	2	1 $\frac{1}{2}$
Strong stony brown Clay	-	18	16
Clay with Sand threads	-	7	12
Wet Sand	-	—	2
		<u>65$\frac{1}{2}$</u>	<u>76</u>

No. 10.

		FEET.
Water	-	18 $\frac{1}{2}$
Silt and Sand	-	6 $\frac{1}{2}$
Peat	-	3
Soft stony brown Clay	-	6
Wet Sand	-	1
Clay with Sand threads	-	23
Strong stony brown Clay	-	9 $\frac{1}{2}$
Clay with Sand threads	-	7
Wet Sand	-	8
		<u>80$\frac{1}{2}$</u>

		No. 11.	No. 12.
		FEET.	FEET.
Water	-	22	24 $\frac{1}{2}$
Strong stony brown Clay	-	4 $\frac{1}{2}$	5
Wet Sand	-	15 $\frac{1}{2}$	10
Chalk rubble and Sand	-	wanting	1 $\frac{1}{2}$
Strong stony brown Clay	-	18	17
Clay with Sand threads	-	12	12
Wet Sand	-	6	—
		<u>78</u>	<u>70$\frac{1}{2}$</u>

No. 13.

		FEET.
Water	-	28 $\frac{1}{2}$
Soft stony brown Clay	-	4
Loamy Sand	-	1
Strong stony brown Clay	-	7
Wet Sand	-	1 $\frac{1}{2}$
Soft brown Clay	-	5
Strong stony brown Clay	-	15
Clay with Sand threads	-	not stated
Wet Sand	-	—

No. 21.

	FEET.
Water	16
Sand and Silt	7
Strong stony brown Clay	9
Clay with Sand threads	2 $\frac{1}{2}$
Wet Quicksand	11 $\frac{1}{2}$
Strong stony brown Clay	3
Soft loamy Clay with Sand threads	2
	51

No. 23.

	FEET.
Water	16 $\frac{1}{2}$
Gravel [Shingle?]	1
Peat	4
Soft stony brown Clay	2
Strong "	11 $\frac{1}{2}$
Wet loamy Sand	5 $\frac{1}{2}$
Strong stony brown Clay	9
Strong loamy Clay with Sand threads	3
	52 $\frac{1}{2}$

No. 24.

	FEET.
Water	12 $\frac{1}{2}$
Sand and Silt	6
Peat	3
Wet Sand	2
Soft stony brown Clay	2
Strong "	10
Damp Sand	8
Strong stony brown Clay	5 $\frac{1}{2}$
Clay with Sand threads	3 $\frac{1}{2}$
	52 $\frac{1}{2}$

No. 26. No. 27.

	FEET.	FEET.
Water	17 $\frac{1}{2}$	15 $\frac{1}{2}$
Sand and Silt	10	18
Damp Sand	15	9 $\frac{1}{2}$
Strong stony brown Clay	8	7
Clay with Sand threads	4	3 $\frac{1}{2}$
	54 $\frac{1}{2}$	53 $\frac{1}{2}$

No. 28. No. 29.

	FEET.	FEET.
Water	15	2 $\frac{1}{2}$
Sand and Silt	23 $\frac{1}{2}$	19 $\frac{1}{2}$
Strong stony brown Clay	—	4 $\frac{1}{2}$
Soft	—	6
Strong " "	8	15 $\frac{1}{2}$
Clay with Sand threads	18 $\frac{1}{2}$	18 $\frac{1}{2}$
Chalk rubble	—	5
	65	71 $\frac{1}{2}$

HULL. New Docks.

B. H. in No. 2. Graving Dock, 26 feet 8 inches below High-water Mark.

Communicated by MR. HURSTWITZ, Resident Engineer, (to MR. CAMERON).

	FEET.
1. Clay with Peat and Gravel	2
2. Stiff brown Clay	4
3. Sandy Clay or Warp	8
4. Coarse and sharp sand and water	9
Stiff Clay	at 50

B. H., No. 1. Trial Pit B. H.

	FEET.
1. Soil	1
2. Clay	9
3. Warp	6·9
4. Silt	12·9
5. Sand	10·0
6. Black Silt	1·6
7. Quicksand	8·5
8. Clay	at 50·4 below H.W.

No. 2. B. H. in Graving Dock begins at No. 4. in No. 1. B. H. Trial Pit.

HULL. North Bridge.

G. SMALLEY, sinker. [S.V.W.]

	FEET.
Alluvium, { Black Warp	25
31 feet. { Dark Sand	5
Peat	1
Drift, { Marl [Boulder Clay]	23
46 feet. { Sand and Gravel	23
To Chalk	77
In Chalk	53
	<hr/> 130

HULL. Carman Street, near St. Stephen's Church.

G. SMALLEY, sinker. [S.V.W.]

	FEET.
Alluvium, { Clay	5
25 feet. { Sand and Gravel	19
Peat Moss	1
Drift, { Marl [Boulder Clay]	17
27 feet. { Sand and Gravel	10
To Chalk	52
In Chalk	109
	<hr/> 161

HUMBER BED, between Hessle and Barton.

Borings made for the North-Eastern Railway.

Communicated by MR. KELSEY.

Bore-hole No. 2, 300 yards east of Hessle Ferry. (Commences at level of high-water.)

						FEET.
Yellow clay	-	-	-	-	-	6
Light-coloured warp clay	-	-	-	-	-	7
Soft dark warp clay	-	-	-	-	-	7
A little stronger warped	-	-	-	-	-	5
Dark peat	-	-	-	-	-	7½
Clay and Gravel	-	-	-	-	-	2½
Pebbles and flinty Gravel	-	-	-	-	-	3½
Light-coloured warp	-	-	-	-	-	2
Fine sand and loose Chalk	-	-	-	-	-	2
						—
			To Chalk	-	-	42½
Bed-coloured loose Chalk	-	-	-	-	-	7½
White Chalk and flint	-	-	-	-	-	16
						—
						66
						—

Bore-hole No. 3, 7 chains south of No. 2, and immediately within the Humber bank. (Commences at level of high water.)

						FEET.
Yellow warped clay	-	-	-	-	-	7
Black silty warp	-	-	-	-	-	16
Blue warp and turf	-	-	-	-	-	11
Yellow warp	-	-	-	-	-	4
Warped Chalk, gravel, and flint	-	-	-	-	-	6
						—
			To Chalk	-	-	44
Red coloured Chalk.	-	-	-	-	-	10
White Chalk and flint, full of water	-	-	-	-	-	14
						—
						68
						—

Bore-hole No 4, 10 chains south of No. 3 (in 26 feet of water).

						FEET.
Peat	-	-	-	-	-	1½
Blue warp and peat	-	-	-	-	-	3
Yellow clay	-	-	-	-	-	10½
Fine gritty Chalk and sand	-	-	-	-	-	½
Yellow warp	-	-	-	-	-	2
Yellow sandy warp	-	-	-	-	-	4
Sand, pebbles, and loose Chalk	-	-	-	-	-	3
						—
			To Chalk	-	-	24½
White Chalk and flint, full of water	-	-	-	-	-	30
						—
						54½
						—

Bore-hole No 8, 10 chains south of No. 4 (in 33½ feet of water).				
				FEET.
Black warped sand	-	-	-	19
Warped sand and gravel	-	-	-	3
				—
	To Chalk	-	-	22
Loose yellow Chalk and flint	-	-	-	8
White Chalk and flint	-	-	-	9
Very soft Chalk	-	-	-	6
White Chalk	-	-	-	6
				—
				51

Bore-hole No. 7, 8 chains south of No. 8 (in 33 feet of water).				
				FEET.
Fine Sand, to Chalk	-	-	-	23
Loose Yellow Chalk	-	-	-	9
White Chalk and flint, full of water	-	-	-	16
				—
				48

Bore-hole No. 11, 12 chains south of No. 7 (in 36½ feet of water).				
				FEET.
Fine quick boiling Sand	-	-	-	18
Dark loamy Sand	-	-	-	9
	To Chalk	-	-	27
White Chalk, full of water	-	-	-	4
				—
				31

Bore-hole No. 9, 12 chains south of No. 11 (in 39 feet of water).				
				FEET.
Quick boiling sand	-	-	-	25
Dark loamy sand	-	-	-	10
	To Chalk	-	-	35
Chalk, full of water	-	-	-	4
				—
				39

Bore-hole No. 10, 17 chains south of No 9 (in 27½ feet of water).				
				FEET.
Fine light sand	-	-	-	25½
Coarse dark sand	-	-	-	22½
	To Chalk	-	-	48
White Chalk	-	-	-	3
				—
				51

Bore-hole No. 12, 26 chains south of No. 10 (in 24 feet of water).				
				FEET.
Loamy sand	-	-	-	25
Coarse sand and Gravel	-	-	-	11
Sand, coarse Gravel, and Chalk pebbles	-	-	-	5
	To Chalk	-	-	41
White Chalk	-	-	-	5
				—
				46

Bore-hole No. 6, 10 chains south of No. 12 (in 25½ feet of water).

	FEET.
Sandy warp	7
Strong marl	10
Fine Sand, full of water	25
Soft red clay	2
Sand and Gravel	4½
Strong marl [Boulder Clay]	7
Gravel	3
Chalk not reached at	<u>58½</u>

Bore-hole No. 5, 22 chains south of No. 6 and immediately within the Humber bank about ¼ mile east of Barton Water Side (commences on the warp about 3 feet below high-water level).

	FEET.
Red clay	8½
Peat	3
Coarse sand	20
Strong clay, small chalk stones [Boulder Clay]	8
Soft warp	28
Strong fine clay	5
Chalk not reached at	<u>72½</u>

IMMINGHAM.

Communicated by MR. SMITH.

	FEET.
Boulder Clay	42 to 45
Sand	4 to 8
Clay	about 1
Gravel and sand	4 to 10
To Chalk	<u>70 to 80</u>

IMMINGHAM Marsh.

Communicated by MR. SMITH.

	FEET.
Blue warp	30
Rotten wood	1 to 3
Warp clay (bluer)	30

Near the Humber the Warp is more sandy.

KELK.

Communicated by MR. J. VILLIERS.

	FEET.
Strong blue clay	60
White gravel	3
To Chalk	<u>63</u>

KEYINGHAM Station.

PRESTWICH, *Quart. Journ. Soc. Geol.*, vol. xvii. p. 456.

	FEET.
Strong clay	12
Marl with stones	3
Sand bed with sufficient water	—

South KILLINGHOLME Haven, about $\frac{1}{2}$ mile N.W. of.

Communicated by MR. WESTABY.

	FEET.
Warp and silt sand	50
Chalk	—

KILLINEHOLME Haven, Tile Kiln S. of.

Communicated by MR. WESTABY.

	FEET.
Warp	about 50
Chalk	—

KILLINGHOLME. Near the School House.

Communicated by MR. JOHN SMITH, Immingham.

	FEET.
Well sunk in clay	24
Bored	60
	—
To Chalk	84
	—

KILLINGHOLME. Coast Guard Station.

Communicated by MR. SMITH.

	FEET.
Warp, the lower part alternating Chalk and Clay [part probably Boulder Clay], rock not touched	107
150 yards inland water was obtained at 54 or 56 feet in shingly gravel.	

LIMBER. At Mr. Frankish's.

Communicated by MR. JOHN SMITH.

	FEET.
Chalk with layers of flint	168

LIMBER. At Mr. Iles' Farm.

Communicated by MR. WESTABY.

	FEET.
Clay with stones	12
Gravel	6
	—
To Chalk	18
	—

Between MAPPLETON and Hornsea.

Communicated by MR. VILLIERS, of Beverley.

	FEET.
Stony blue clay	40
Sand	10
Clay	50
Sand and gravel with shells	32
	—
To Chalk	132
	—

MARFLEET Station.

PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. xvii. p. 456.

	FEET.
Warp	30

Salt water sprang from "rotten stuff."

MARSH CHAPEL. Several wells.
Communicated by MR. W. SARGENT.

							FEET.
Soil and Clay	-	-	-	-	-	-	9
Black mud	-	-	-	-	-	-	21
Layer of wood	-	-	-	-	-	-	1
Clay and sand	-	-	-	-	-	-	54
			To Chalk	-	-	-	85

NAFFERTON STATION.
Communicated by MR. J. VILLIERS.

							FEET.
Very soft Warp clay	-	-	-	-	-	-	about 13
White gravel, full of water	-	-	-	-	-	-	10
Chalk, very small rotten stuff	-	-	-	-	-	-	25
			To Chalk	-	-	-	48
Solid Chalk	-	-	-	-	-	-	162
							210

NEW HOLLAND.

Communicated by MR. SAMPSON to MR. PENNING.

							FEET.
Well, to Greensand [?]	-	-	-	-	-	-	320

NEW HOLLAND. Pier Head.

Communicated by MR. WESTABY.

							FEET.
Warp	-	-	-	-	-	-	?
Hard clay with stones	-	-	-	-	-	-	30
Chalk (falls 3 feet from New Holland)	-	-	-	-	-	-	

NEW HOLLAND. Jackson's Brick Yard.

Communicated by MR. J. SMALLEY.

							FEET.
To rock	-	-	-	-	-	-	46

NEW HOLLAND. Near the Railway Junction.

Communicated by MR. WESTABY.

							FEET.
Brick clay (warp)	-	-	-	-	-	-	7
Warp	-	-	-	-	-	-	20
Peat with wood	-	-	-	-	-	-	2 to 4
Sand	-	-	-	-	-	-	3
Clean brown clay	-	-	-	-	-	-	about 17
			To Chalk	-	-	-	50

NEW HOLLAND to BARROW FERRY.

Communicated by MR. WESTABY.

For a mile the depth to the rock is about 50 feet, the top of the Chalk being very level.

NORTH COTES Fitties.

Communicated by MR. JOSEPH JACKLING.

							FEET.
To Chalk (rather soft)	-	-	-	-	-	-	about 84 to 90

NORTH COTES. (Several wells.)

Communicated by MR. JOSEPH JACKLING.

	FEET.
Warp	60
Sand	1½
Dark stiff clay with a few stones	15 to 18
Sand with stones	½ to 3
To Hard Chalk	85

NORTH COTES. Near Tetney.

Information from a well-sinker at Louth (to MR. JUKES-BROWNE).

	FEET.
Reddish clay	5
Silt and "moor"	40
Blue clay with stones	30
Sand	6
Chalk touched	2
	83

NORTH COTES Parsonage.

Communicated by MR. JOSEPH JACKLING.

At 11 yards down leaves and wood were found.

NORTH FERRIBY.

	FEET.
Sank } all strong blue clay, no particulars	15
Bored }	155
	170

Well deepened to 200 feet, when Chalk was reached and water.

NORTH FERRIBY LANDING. New red brick house.

	FEET.
Sank in Silty clay	24
Bored in Strong clay	10
	34

NORTH THORESBY. Engine yard.

Communicated by MR. JOSEPH JACKLING.

	FEET.
Clay with stones	81
Sand (thin bed)	—
Chalk	—

NORTH THORESBY. Near the Granby Inn.

Communicated by MR. JOSEPH JACKLING.

	FEET.
Boulder Clay	48
Gravel	10

OTTRINGHAM MARSH. PROF. J. PHILLIPS' *Illustrations of the Geology of Yorkshire*, ed. 3, p. 66.

"The layer of peat, one yard thick, was found 41 yards beneath the surface; 36 yards of various diluvial matter lay beneath; and the Chalk was found at the depth of 78 yards."

[The above measurements evidently should be *feet*, not *yards*.]

OTTRINGHAM. Where the Ottringham Road crosses the railway.

PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. xvii. p. 456.

	FEET.
Strong marl with stones, no water	30

PATRINGTON Station.

							FEET.
Strong red marl	-	-	-	-	-	-	30
Grey marl with stones	-	-	-	-	-	-	15
Sand with water	-	-	-	-	-	-	—
							45

PAULL. Saltend. 1861.

Information from G. SMALLEY, sinker. [S.V.W.]

							FEET.
Clay [Warp and perhaps Boulder Clay]	-	-	-	-	-	-	about 100
Sand, gravel and small cockles [probably Inter-glacial Gravels]	-	-	-	-	-	-	about 14
							—
To Chalk	-	-	-	-	-	-	114
In Chalk	-	-	-	-	-	-	46
							—
							160

PAULL. 650 ft. from the Cliff, 24 ft. above H.W.M. [S.V.W.]

FEET.

Coarse sand	-	-	-	-	-	-	20
Fine sand	-	-	-	-	-	-	8
The well is sunk on the edge of a bank of Clay, the lower 8 ft. being in the Clay on one side.							

PRESTON. South of Cold Harbour.

MESSRS. R. & S. BRUMBY.

							FEET.
Warp	-	-	-	-	-	-	4
Peat	-	-	-	-	-	-	1
Gravel	-	-	-	-	-	-	8-10
Chalk	-	-	-	-	-	-	about 55
							—
							70

RISE. Mr. Bethel's. 1864.

Information from G. SMALLEY, sinker. [S.V.W.]

							FEET.
Marl	-	-	-	-	-	-	10
Grey sand	-	-	-	-	-	-	2
Clayey sand	-	-	-	-	-	-	18
Clay [Boulder Clay]	-	-	-	-	-	-	34
Sand	-	-	-	-	-	-	8
Clay	{	{	{	{	{	{	30
Sand 5 inches							
Clay							
Sand 5 inches							
Cobbles	{	{	{	{	{	{	16
Clay 4 ft.							
Sand	{	{	{	{	{	{	4
Clay 4 ft.							
Sand	{	{	{	{	{	{	4
Small Gravel							
Sand	{	{	{	{	{	{	2
Gravel							
Marl	-	-	-	-	-	-	—
Gravel	-	-	-	-	-	-	—
Conglomerate	-	-	-	-	-	-	—
							382
							—
To Chalk	-	-	-	-	-	-	128
In Chalk	-	-	-	-	-	-	254
							—

ROUTH.

Communicated by MR. VILLIERS.

	FEET.
Fine sand (perhaps alternations of clay and sand)	40
Blue clay	10
To Chalk	50

SKIRLAUGH.

Communicated by MR. J. SMALLEY.

	FEET.
Boulder Clay	60
Sand	6
Boulder Clay	28
Gravel	2
To Chalk	96

SOUTH SOMERCOTES.

Communicated by MR. JOSEPH JACKLING.

	FEET.
Clay	27
Black soft clay	45
Sand	4
Strong clay	12 to 15
Sand	1
To Chalk	90
Chalk (very soft, like putty)	39
	129

SPURN High Lighthouse, boring made about 1860. [Mr. Pickwell.]

	FEET.
Shingle	50 or 60
The water rose and fell with the tide, and corresponded nearly with the sea, both in level and taste.	

SPURN HEAD. Shallow well sunk about 1780. [Smeaton.]

	FEET.
Sand	5 or 6
The water was only slightly brackish, and was unaffected by the tide.	

STALLINGBOROUGH and KILLINGHOLME.

Borings made in 1874; communicated by MR. FISHER.

No. 1. Outside the sea bank 50 feet S.E. of the Signal Post next Stallingborough Creek.

	FEET.
Brick clay	7
Soft clay and warp	13
Wood, silt, and soft clay	6
Soft warp	16
Hard marl clay [Boulder Clay]	5
Small gravel	3
Hard marl clay [Boulder Clay]	10
Clean loose sand	4
To Chalk	68 ?

No. 2. Inside the sea bank 133 yards N.W. of No. 1.

	FEET.
Brick clay	5
Soft blue silt	35
Clay and old timber	4
Hard marl clay [Boulder Clay]	3
Small gravel and sand	3
Hard clay, as above [Boulder Clay]	12
Loose sand	5
Hard clay	4
	<hr/>
Chalk	71
	<hr/>
	5
	<hr/>
	76
	<hr/>

No. 7. $\frac{1}{4}$ mile N.W. of the Battery Grounds.

	FEET.
Brick clay	10
Soft blue clay	15
Blue silt	17
Wood and clay	2
Loose red sand	12
Soft clay	2
Loose red sand	6
Smooth brown brick clay	14
	<hr/>
	78
	<hr/>

No. 10. $\frac{1}{4}$ mile S. of S. KILLINGHOLME Haven.

	FEET.
Brick clay	6
Soft blue clay	12
Blue silt	8
Wood and clay	2
Strong blue clay	14
Silt and loose sand	4
Good brown clay	9
Loose sand and gravel	7
Brown clay	1
Small gravel	1
Blue clay and sand, in thin beds	$7\frac{1}{2}$
Hard marl clay	$2\frac{1}{2}$
	<hr/>
	74
	<hr/>

No. 11. $\frac{1}{4}$ mile S.E. of NORTH KILLINGHOLME Haven.

	FEET.
Chalk at	55

No. 14. $\frac{1}{2}$ mile N.W. of HALTON SKITTER Haven.

	FEET.
Brick clay	6
Soft blue clay and silt	24
Hard marl clay [Boulder Clay]	10
Soft Chalk	5
	<hr/>
Hard Chalk at	45
	<hr/>

SUNK ISLAND. Tracing by Rev. J. L. ROME. [S.V.W.]

SUNK ISLAND [exact locality not stated]. Tracing by
REV. J. L. ROME. [S.V.W.]

			FT.	IN.
Alluvium, 34 $\frac{1}{4}$ feet.	Soil	-	-	1 6
	Brown marl	-	-	4 3
	Black and brown sand	-	-	1 11
	Brown sand	-	-	1 7
	Fine sand	-	-	25 0
	Brown clay with chalk pebbles, &c.	-	-	19 4
	Red clay and pebbles	-	-	6 0
	Fine brown clay	-	-	1 0
	Brown clay and chalk	-	-	26 4
Drift, 79 $\frac{1}{2}$ feet.	Fine brown clay	-	-	2 6
	Fine grit sand	-	-	2 0
	Gravel	-	-	6 2
	Blue flint and sand	-	-	1 0
	Fine brown clay	-	-	1 4
	Clay, chalk and pebbles	-	-	9 0
	Lead-coloured clay	-	-	1 0

SUNK ISLAND. Church. [Perhaps the same as the last section.]

OLDHAM, *Rep. Brit. Assoc.* for 1853, p. 37.

TETNEY. Near the Blow Wells.

Communicated by MR. JOSEPH JACKLING.

Clay - - - - - Chalk - - - - - F.EET. - - - - - 63
 Water rises seven or eight feet above the surface.

Water rises seven or eight feet above the surface.

TETNEY Village.

Communicated by MR. JOSEPH JACKLING.

							FEET.
Boulder Clay	-	-	-	-	-	-	81
Rock [Chalk]	-	-	-	-	-	-	-

TETNEY.

Communicated by MR. JOSEPH JACKLING.

	FEET.
To hard Chalk	81

THORNTON COLLEGE. Immediately N. of.

Communicated by MR. WESTABY.

	FEET.
Sand	6
Clay	30
To Chalk	<u>36</u>

THORNTON MARSH. New Farm on.

Communicated by MR. WESTABY.

	FEET.
Sand	6
Clay	42
To Chalk	<u>48</u>

WILLERBY. Town pump.

G. SMALLEY, sinker. [S.V.W.]

	FEET.
Clay (Hessle)	about 15
Clay and Chalk débris	10
To Chalk	about 25
In Chalk	65
	<u>90</u>

WINESTEAD Gate-house.

PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. xvii. p. 456.

	FEET.
Warp	30
Strong red marl	5
Marl with stones	30
Dirty sand with water	<u>65</u>

WITHERNSEA Station.

PRESTWICH, *Quart. Journ. Geol. Soc.*, vol. xvii. p. 456.

	FEET.
Clay marl	15
Gravel and sand	5
Strong marl with stones	60
Gray sand and shells, with water	<u>2</u>
	<u>82</u>

▲ 16165.

L

WITHERNSEA. Simpson's Brick-yard.

Communicated by MR. J. SMALLEY.

						FEET.
Depth of well						61
Bored from bottom of well to rock						89.
						<hr/>
	To Chalk					150
Chalk						67
						<hr/>
						217

Bridge over the Ouse on the Hull and Doncaster Branch of the
North-eastern Railway.From a section of the river bed in possession of
S. V. Wood, Esq., jun.

[Inserted for comparison with the borings near Hull].

Boring 1. About 8 feet from spring tide highwater mark on the Hook side	2. In the river 200 feet from 1.	3. " 200 "	4. " 205 "	5. " 210 "	4 near H.W.M. on the Skelton side.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Water at spring tides					0	15	19½	27	1	
Silt and sand					22	7½	3	3	19	
Black peat					16	15	16½	10	18	
Wet sand and gravel					3½	12	4½	4½	3	
Soft brown clay					3	0	2½	1½	1	
Wet sand and gravel					5½	0	5	6	7	
Soft brown shale or loamy clay					0	0	0	2	6	
Soft blue shale					15	15½	18	15½	10	
Strong blue shale (not pierced)					10	4	5	5	30	
Depth from spring tide high water					<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
					75	69	74	74½	95	

APPENDIX II.

LIST OF WORKS ON HOLDERNESS.

1662.

DUGDALE, [SIR] WILLIAM. *The History of Imbanking and Drayning of Divers Fens and Marshes, Both in Forein Parts, And in this Kingdom; And of the Improvements thereby.* *London.* [2nd edit. Revised and corrected by C. N. Cole. Fol. *London, 1772.*]

1685.

CALLIS, ROBERT.—*Readings on the Statute of Sewers.* 2nd edit. 4to.

1687? [Published 1760.]

COLLINS, CAPT. G.—*Great Britain's Coasting Pilot.* Fol.

1739.

SCOTT, J.—*Draft of the River Humber.* 4th edit. *Hull.* Engraved and printed by I. Hilbert.

1784.

PENNANT, THOS.—*Arctic Zoology.* 4to. *London.* Vol. 1. Contains an account of the loss of land in Holderness.]

1786.

TUKE's Map of Holderness. *See* POULSON, 1840.

1791.

SMEATON, JOHN.—*Narrative of the Building of the Eddystone Light-house, &c.* Fol. *London, 1813.* 2nd edit.

1799.

YOUNG, ARTHUR.—*Agricultural Survey of Lincolnshire.* 8vo.

1800.

STONE, THOMAS.—*Review of the corrected Agricultural Survey of Lincolnshire by Arthur Young.* 8vo.

1805.

BLIGH, CAPT.—*A Survey of the Humber, 1797.* (*Admiralty Chart.*)

1812.

STRICKLAND, H. E.—*Agricultural Survey of Yorkshire, East Riding.* 8vo. *York.*

1815.

STOREE, DR. J.—*On an Ebbing and Flowing Stream discovered by boring in the Harbour of Bridlington.* *Phil. Trans.*, vol. cv., part 1, p. 55; and *Phil. Mag.*, vol. xlvi. p. 432.

1816.

BOGG, E.—*A Sketch of the Geology of the Lincolnshire Wolds.* *Trans. Geol. Soc.*, vol. iii. p. 392.

STEVENSON, ROBERT.—*Observations on the Alveus or General Bed of the German Ocean and British Channel.* *Mem. Wern. Soc.*, vol. ii. pp. 464-490.

1817.

ANON.—The Ebbing and Flowing Stream in the Harbour of Bridlington, Yorkshire. *Phil. Mag.*, vol. xlix. p. 230.

— (W. S.)—On Ebbing and Flowing Springs. *Phil. Mag.*, vol. i. p. 267.

INGLIS, G.—On the Cause of Ebbing and Flowing Springs (Bridlington). *Phil. Mag.*, vol. i. p. 81.

1820.

STEVENSON, ROBERT.—On the Bed of the German Ocean, or North Sea. *Mem. of the Wernerian Soc.*, vol. iii. pp. 314–336.

1822.

ANON.—Fossil Remains [Atwick near Hornsea]. *Phil. Mag.*, vol. ix. p. 154.

YOUNG, REV. GEO. AND J. BIRD.—A Geological Survey of the Yorkshire Coast. 4to. [2nd edit. in 1828.]

1823.

BUCKLAND, REV. PROF. W.—*Reliquiae Diluvianæ*. 4to.

1824.

Ordnance Survey Map, scale 1 inch to 1 mile. Sheets 85 and 86.

1825.

SEGWICK, REV. PROF. A.—On the Origin of Alluvial and Diluvial Formations. [Yorkshire, pp. 243, 244.] *Ann. of Phil.*, ser. 2, vol. ix. p. 241, and vol. x. p. 18.

1826.

SEGWICK, REV. PROF. A.—On the Classification of the Strata which appear on the Yorkshire Coast. *Ann. of Phil.*, ser. 2, vol. xi., p. 339.

WHITE, W.—The Directory, Guide, and Annals of Kingston-upon-Hull. *Leeds.* 12mo.

1827.

PHILLIPS, [PROF.] J.—On the Direction of the Diluvial Currents in Yorkshire. *Phil. Mag.*, ser. 2, vol. ii. p. 138.

1829.

PHILLIPS, PROF. J.—Illustrations of the Geology of Yorkshire, or a Description of the Strata and Organic Remains of the Yorkshire Coast. 4to. *York.* Edit. 2nd, in 1835.

1831.

ALLEN, THOMAS.—A New and Complete History of the County of York. 4to.

1833.

LYELL, [SIR] CHARLES.—Principles of Geology. 8vo. vol. i. [Many later editions.]

1834.

PHILLIPS, PROF. J.—On the Ancient and partly buried Forests of Holderness. *Phil. Mag.*, ser. 3, vol. iv., p. 282.

1835.

BEAN, W.—A short Account of an interesting Deposit of Fossil Shells at Burlington Quay. *Mag. Nat. Hist.*, vol. viii. p. 355.

1836.

PHILLIPS, PROF. J.—Notice of a newly discovered Tertiary Deposit on the Coast of Yorkshire (Bridlington). *Rep. Brit. Assoc. for 1835, Trans. of Sections*, p. 62.

1839.

LYELL, [SIR] C.—On the Relative Ages of the Tertiary Deposits commonly called “Crag,” in the Counties of Norfolk and Suffolk. (Yorkshire, p. 323.) *Mag. Nat. Hist.*, ser. 2, vol. iii. p. 313.

1840.

POULSON, GEORGE.—History of Holderness. 4to. *Hull.* [Contains TUKE’s Map of 1786.]

1843.

PUSEY, P.—On the Agricultural Improvements of Lincolnshire. *Journ. Royal Agric. Soc.*, vol. iv. pp. 287–316.

1845.

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FORBES, PROF. E.—On the Connexion between the Distribution of the existing Fauna and Flora of the British Isles, and the Geological Changes which have affected their area, especially during the epoch of the Northern Drift. *Mem. Geol. Survey*, vol. i. pp. 336–432.

1848.

LEGARD, G.—Farming of the East Riding of Yorkshire. *Journ. Royal Agric. Soc.*, vol. ix. p. 85; and *Trans. York. Agric. Soc.*, no. xi. p. 69.

1851.

CLARKE, J. A.—Farming of Lincolnshire. *Journ. Royal Agric. Soc.*, vol. xii. pp. 259–414.

1852.

SORBY, H. C.—On the Contorted Stratification of the Drift of the Coast of Yorkshire. *Proc. Geol. Soc. Yorkshire*, vol. iii. p. 220.

1853.

PHILLIPS, PROF. J.—The Rivers, Mountains, and Seacoast of Yorkshire. 8vo. *Lond.* [Edit. 2 in 1855.]

—.—A Map of the Principal Features of the Geology of Yorkshire. (Scale 5 miles to an inch.) *York.* [Edit. 2 in 1862.]

SORBY, H. C.—On the Microscopical Structure of some British Tertiary and Post-tertiary Freshwater Marls and Limestones. [Holderness, p. 345.] *Quart. Journ. Geol. Soc.*, vol. ix. p. 344.

WOOD, S. V.—A Monograph of the Crag Mollusca. pt. 2. [Yorkshire. pp. 168, 179, 182–184, 187, 196.] *Pal. Soc.*

1854.

BELL, DR. J. P.—Observations on the Character and Measurements of Degradation of the Yorkshire Coast. *Rep. Brit. Assoc. for 1853*, p. 81.

KEMP, G. G.—On the Waste of the Holderness Coast. *Rep. Brit. Assoc. for 1853, Trans. of Sections*, p. 53.

OLDHAM, JAS.—On the Physical Features of the Humber. *Rep. Brit. Assoc. for 1853*, p. 36.

SOLLITT, J. D.—On the Chemical Constitution of the Humber Deposits. *Rep. Brit. Assoc. for 1853, Trans. of Sections*, p. 49.

1854-1855.

Ordnance Survey Map, Yorkshire, scale 6 inches to 1 mile. Sheets 128, 129, 146, 163, 180, 197, 212, 213, 228, 242, 243, 257, 269, 269a. [Surveyed in 1852-3.]

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1857.

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1858.

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1859.

ANON. (W.)—The Deposition of Warp. *Geologist*, vol. ii. p. 490.

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TROLLOPE, REV. E.—On the Alluvial Lands, and Submarine Forests of Lincolnshire. *Proc. Geol. Soc. Yorkshire*, vol. iii. p. 637.

1860.

TINDALL, EDWARD.—[Letter on] Mammalian Remains at Bridlington. *Geologist*, vol. iii. p. 119.

1861.

MURRAY, JOHN.—On the North Sea; with Remarks on some of its Friths and Estuaries. *Proc. Inst. Civ. Eng.*, vol. xx. p. 314.

PRESTWICH, J.—On the Occurrence of the Cyrena fluminalis, together with Marine Shells of Recent Species, in Beds of Sand and Gravel over Beds of Boulder Clay near Hull. *Quart. Journ. Geol. Soc.*, vol. xvii. p. 446.

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1864.

TINDALL, E.—[Letter on] the Present State of the Bridlington Crag. *Geol. Mag.*, vol. i. p. 142.

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WOODWARD, S. P.—Remarks on the Bridlington Crag, with a List of its Fossil Shells. *Geol. Mag.*, vol. i. pp. 49, 142.

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PECHELL, A. H.—[Letter] on Magnetic Pyrites from Barton. *Geol. Mag.*, vol. ii. p. 234.

SIMPSON, M.—The Drift of the East of England. *Geol. and Nat. Hist. Repertory*, vol. i. p. 57.

1866.

JONES, PROF. T. R., W. K. PARKER, and H. B. BRADY.—A Monograph of the Foraminifera of the Crag. Part I. [Bridlington, Plate 4.] *Pal. Soc.*
OLDHAM, JAS.—Evidence before the Select Committee of the Lords on the Holderness Embankment and Reclamation Bill, April 1866.

1867.

FOSTER, DR.—On the Discovery of Ancient Trees below the Surface of the Land, at the Western Dock, now being constructed at Hull. *Rep. Brit. Assoc. for 1866, Trans. of Sections*, p. 52.
HALL, H. F.—Drift Sections of the Holderness Coast. *Proc. Liverpool, Geol. Soc.*, Session 8, p. 12.
—.—Lacustrine Deposits of Holderness. *Ibid.*, p. 38.

1868.

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WOOD, S. V., jun., and REV. J. L. ROME. On the Glacial and Post-glacial Structure of Lincolnshire and South-east Yorkshire. *Quart. Journ. Geol. Soc.*, vol. xxiv. p. 146.

1869.

JENKINS, H. M.—Eastburn Farm, near Driffield, Yorkshire. *Journ. Royal Agric. Soc.*, ser. 2., vol. v., pp. 399–414. [Geological Map by J. R. MORTIMER.]
—.—Aylesby, Riby, and Rothwell Farms, near Grimsby, &c. *Journ. Royal Agric. Soc.*, ser. 2., vol. v., pp. 415–442.
SHELFORD, W.—On the Outfall of the River Humber. *Proc. Inst. Civ. Eng.*, vol. xxviii., p. 472. [With long discussion by Messrs. Bateman, Belcher, Coode, Harrison, and Redman.]
TYLOR, A.—On Quaternary Gravels. [Yorkshire, p. 61]. *Quart. Journ. Geol. Soc.*, vol. xxv. p. 57.

1870.

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Report of the case of Williams v. Nicholson, for removing Shingle from the Foreshore at Withernsea, &c. 8vo. London, pp. 1–52.
TINDALL, E.—Remarks on the Extinct Fauna of the East Riding of Yorkshire. *Proc. Geol. Soc. Yorkshire*, vol. v. p. 7.
WOOD, S. V., jun.—On the Relation of the Boulder Clay, without Chalk, of the North of England to the Great Chalky Boulder Clay of the south. *Quart. Journ. Geol. Soc.*, vol. xxvi. p. 90.
—.—Observations on the Sequence of the Glacial Beds. *Geol. Mag.*, vol. vii. pp. 17, 61.

1871.

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—.—Further Remarks on Mr. James Geikie's Correlation of Glacial Deposits. *Geol. Mag.*, vol. ix. p. 352.

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WOOD, S. V., jun.—American "Surface Geology," and its Relation to British. *Geol. Mag.*, dec. ii., vol. iv., pp. 481-496, 536-551.

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CLARKE, J. A.—Practical Agriculture. *Journ. Royal Agric. Soc.*, 2nd ser., vol. xiv., pp. 611-616.

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—.—The Purple Boulder Clay at Holderness. *Geol. Mag.*, dec. ii., vol. vi., p. 528.

—.—Glacial Beds at Bridlington. *Proc. Geol. Soc. Yorkshire*, n.s., vol. vii., pt. 2., pp. 123-128. Pl. vii., viii., ix.

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